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Advanced Distributed Simulation for the Australian Defence Force

Peter Clark, Peter Ryan and Lucien Zalcman

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ABSTRACT

To address long standing problems with modelling and simulation, the US Department of Defence through the Defense Modeling and Simulation Office (DMSO) has initiated a comprehensive series of programs. These programs aim to promote interoperability, code and model reuse, data standardisation, common conceptual models of military operations, and Validation, Verification & Accreditation (VV&A), among other important issues, through a Common Technical Framework. A key issue for Australia is the means of networking simulators together. The US DoD has mandated the High Level Architecture (HLA) which has technical advantages over the previous standard, Distributed Interactive Simulation (DIS). The advantages and disadvantages of each approach are discussed in the Australian context. Other related programs such as the Synthetic Environment Data Representation and Interchange Specification (SEDRIS), Conceptual Models of Mission Space, Master Environment Library, Data Engineering, and VV&A programs are discussed in the Australian context. The authors recommend a cautious approach to the introduction of HLA into the ADO following the US experience. Through appropriate Defence Exchange Agreements the ADO can work with the US and our other allies (particularly the UK) to ensure that ADF in-service training systems will migrate to HLA while retaining interoperability.

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Executive Summary

To address long standing problems with modelling and simulation, the US through the Defense Modeling and Simulation Office, has initiated a comprehensive series of programs. These programs aim to promote interoperability, code and model reuse, data standardisation, common conceptual models of military operations, and VV&A, among other important issues, through a Common Technical Framework.

A key issue for Australia is the means of networking simulators together. The US DoD has mandated the High Level Architecture (HLA) which has technical advantages over the previous standard, Distributed Interactive Simulation (DIS). HLA provides greater flexibility compared to the rigid requirements to achieve DIS compliance. However this flexibility can also be a disadvantage since all participating simulations must agree on which information to interchange. This limits those players wanting to interoperate to agree before hand on such specifications, and may compromise the open interoperability that is a key feature of DIS.

The Australian Defence Organisation (ADO) is moving towards Advanced Distributed Simulation to enhance its training capability and is gaining experience with DIS. Should the ADO consider HLA for its simulators and simulations or persist with DIS? This document addresses these issues from an Australian perspective.

Apart from HLA, DMSO has introduced various other related programs in an attempt to simplify the development of models and simulation. The Synthetic Environment Data Representation and Interchange Specification (SEDRIS), Conceptual Models of the Mission Space, Master Environment Library, and Data Engineering programs are discussed in the Australian context. Verification, Validation and Accreditation (VV&A) is another important issue for Australia to consider in developing models and simulations for defence purposes.

Australia has recently established the Australian Defence Simulation Office (ADSO) to provide policy guidance, coordination, and to foster collaboration across Defence, industry, and through international organisations such as the Simulation Interoperability Standards Organisation (SISO) and the International Simulation Advisory Group (ISAG).

For real time, Australian Defence Force (ADF) military tactical simulators (especially those to be used primarily for training), the authors recommend DIS as the current

networking standard. Such simulators require the flexibility to interoperate with other simulators, but it may not be known in advance (at the time of development and deployment) with which other simulators they might interoperate. The advantage of DIS is that all DIS-enabled simulators can interoperate. With HLA, the exact data transfer mechanism, the FOM, must all be agreed in advance. It is necessary to know with which simulators you wish to network. If HLA is deemed to be absolutely necessary as the networking architecture, then the SISO standard Real time Platform Reference Federation Object Model (RPR-FOM) should be specified.

For research projects and simulations used for analysis, which can be designed to network with other simulations known in advance, the new HLA may be preferred. The Virtual Ship Project is an excellent example of a DSTO research project, where the use of HLA is ideal. Since the interoperability can be planned ahead, the FOM can be tailor-made to suit the application.

HLA is new and exciting technology that will ultimately offer many advantages over DIS. It is an excellent research area for DSTO, with its long tradition of M&S, to investigate in the laboratory environment. An Australian Defence Organisation FOM does not exist and should **not** be developed until agreement is reached on likely allied Nation projects with which Australia wishes to interoperate (eg BFTT). Therefore, it is highly **premature** to mandate its use for the ADO. Mandating HLA would compromise interoperability between ADF in-service (or soon to be in-service) training systems and with the US and other allies.

The authors recommend a cautious approach to the introduction of HLA into the ADO following the US experience. Through appropriate Defence Exchange Agreements the ADO can work with the US and our other allies (particularly the UK) to ensure that ADF in-service training systems will migrate to HLA while retaining interoperability.

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Dr Peter Clark graduated from the Australian National University (ANU) in Canberra with a BSc (Hons) in 1978, and a PhD in Physics in 1981. He joined the Australian Defence Department in 1982. In 1989 he was appointed for a five year period as the Scientific Adviser to Army's HQ Training Command in Sydney. In 1994 he was appointed as a Senior Research Scientist with DSTO's Air Operations Division, where he has worked for the past seven years on a range of topics involving simulation research, with an emphasis on Human-in-the-Loop simulation, intelligent computer-generated forces, and the technologies associated with Advanced Distributed Simulation. Dr Clark served a five year term (1993-1997) as Panel Chairman of the TTCP Technical Panel on Training Technology (HUM-TP2). Dr Clark has held the appointment of Australian Co-chairman of the International Simulation Advisory Group (ISAG) since 1997.

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Dr Peter Ryan is a Senior Research Scientist with the Air Operations Division of DSTO. He graduated from Melbourne University with a BSc (Hons, First Class) in 1975, and awarded a PhD from Melbourne University in 1981. After further research at Melbourne University and postdoctoral work at the University of Massachusetts, USA he joined DSTO in 1985 as a Research Scientist in the Mines Research Group. During 1988-1989 he was a Visiting Scientist at the Admiralty Research Establishment (Bincleaves) at Weymouth, UK. He has an extensive background in Maritime Operations Division on the modelling and simulation of ship/mine encounters and the development of minefield simulation models. In 1998, he joined the Simulation & Human Factors Branch of Air Operations Division and is now working in the field of simulation as applied to both training and also operational evaluation. His main research interests are in applying Advanced Distributed Simulation technology to assist Navy with their training requirements.

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Dr Lucien Zalcman graduated from Melbourne University with a BSc (Hons.) in 1973. He was awarded a PhD in Physics from Melbourne University in 1980. He also completed a Graduate Diploma in Computing Studies at RMIT graduating in 1987. During the period 1980 - 1984 he worked as an Experimental Officer at the CSIRO Division of Mineral Chemistry carrying out research into lead acid batteries for electric vehicles. He joined DSTO in 1984 as an Information Technology Officer in the Computer Centre at the Aeronautical Research Laboratory. In 1992 he was employed as a Senior Professional Officer in Air Operations Division of AMRL specialising in the field of Distributed Interactive Simulation. He was promoted to Senior Research Scientist in 1998.

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1. Introduction

In her presentation [1] at the 17th Interservice /Industry Training Systems and Education Conference (I/ITSEC) in 1995, Dr Anita Jones, then Director of the US Defense Modeling and Simulation Office (DMSO) commenced her keynote address with the remark that US Department of Defense (DoD) simulations:

- are built separately from scratch for each user community,
- take too long to build,
- cost too much to build and to operate,
- have not been verified, validated, and accredited,
- do not use operational C3I systems,
- can be used in concert only with difficulty,
- rarely reuse data among simulations (eg., environmental), and
- can rarely interoperate with instrumented ranges.

To address these issues, DMSO initiated a comprehensive series of programs aimed at promoting interoperability, code and model reuse, data standardisation, and VV&A, among other important issues, through a Common Technical Framework.

A key issue for Australia is the means of networking simulators together. Advanced Distributed Simulation technologies are changing the way in which military forces train and rehearse for missions. By connecting many simulators into a shared virtual world, technologies such as Distributed Interactive Simulation (DIS) can increase training effectiveness [2]. DIS has been very successful in this role but has shown deficiencies in its scalability because of the broadcast technique across many computing nodes in a DIS exercise and in its de facto restriction to real time platform level simulation.

The US DoD has mandated the High Level Architecture (HLA), which will address these deficiencies. Whereas DIS requires compliance to a standard Protocol Data Unit (PDU) set, HLA allows each federate to specify what information it will generate and what data it receives. However, all participating federates must agree on which information to interchange. This then limits those players wanting to interoperate to agree before hand on such specifications, and reduces to a degree the open-interoperability, which is a key feature of DIS.

The Australian Defence Organisation (ADO) is moving towards Advanced Distributed Simulation to enhance its training capability and is gaining experience with DIS. Should the ADO consider HLA for their simulators and simulations or persist with DIS? This document addresses these issues from an Australian perspective.

Apart from HLA, DMSO has introduced various other related programs in an attempt to simplify the development of models and simulation. These will also be discussed in the Australian context.

2. Distributed Interactive Simulation

2.1 Description of DIS

Distributed Interactive Simulation (DIS) is a *networking protocol standard* that provides a method of communicating entity state and other information, such as electronic warfare, through Protocol Data Units (PDUs). DIS, developed from the US Army's SIMNET [3] program, was under development for about 10 years [4 - 6], and is now considered to be a fully mature simulator/simulation networking technology.

Since DIS is an IEEE standard, any simulator connected to the network and implementing the same version of the DIS protocols can participate in a DIS exercise. However, DIS has resource issues in terms of both network bandwidth, and simulator computational impact, because of the broadcast technique applied across many computers in a DIS exercise.

Third party software products, such as Mäk's VRLink toolkit, can interface a simulation to the DIS network allowing it to send and receive correctly formatted PDUs [7]. DIS is most suited for connecting real-time human-in-loop simulators.

The basic concepts of DIS are:

a) *No central computer controls the entire simulation exercise.* DIS uses a distributed simulation approach in which the responsibility for simulating the state of each entity (tank, submarine, carrier, aircraft, missile, etc.) rests with separate simulation applications residing in computers communicating via a network.

b) *Simulation applications are autonomous and are responsible for maintaining the state of one or more simulation entities.* The simulation application is responsible for modelling the actions of its entity or entities using a high fidelity simulation model. That simulation is responsible for sending messages to others, and as necessary, informing them of any observable actions. All simulations are responsible for interpreting and responding to messages of interest from other simulations, and maintaining a model of the state of entities represented in the simulation exercise. This autonomy principle enables simulation nodes to leave or join an exercise which is in progress, without disrupting the rest of the simulation.

c) *A standard protocol is used for communicating ground truth data.* Each simulation application communicates the absolute truth about the state of the entity it controls (location, orientation, velocity, articulated parts position, etc.) to other simulations on the network. The receiving simulation is responsible for taking this ground truth data and calculating whether the entity represented by the sending simulation is detectable by visual or electronic means. This perceived state of the entity is then displayed to the user as required by the individual simulation.

d) *Changes in the state of an entity are communicated by simulation applications.*

e) *Perception of events or other entities is determined by the receiving application.*

f) *Dead reckoning algorithms are used to reduce the communications processing.* A method of position/orientation estimation, called dead reckoning, or "Remote Entity Approximation", is used to limit the rate at which simulations issue state updates for an entity. Each simulation maintains a high fidelity model of the entity it represents. In addition, the simulation maintains a simpler model of its entity, which represents the view of that entity by other simulation applications on the network and is an extrapolation of position and orientation state using a specified dead reckoning algorithm. On a regular basis, the simulation compares the high fidelity and simpler models of the entity. If the difference between the two exceeds a predetermined threshold, the simulation will update the simpler model using the information from the high fidelity model. At the same time, the simulation will send updated information to other simulations on the network so that they can update their model of the entity. If an entity continues to do the same thing (eg. straight and level flight at constant velocity) the update rate drops to a predetermined minimum (heart beat) level. By using dead reckoning, simulations are not required to report the status of their entities every frame.

2.1 DIS Standards

DIS operates by exchanging data messages, known as Protocol Data Units (PDU) on a network between simulation applications. DIS has undergone the IEEE standardisation process three times:

- IEEE 1278-1993 (1993) [4]: 10 PDUs to support the appearance and movement of entities, weapons firing, ordnance detonation, collisions, and logistical resupply of units.
- IEEE 1278.1-1995 (1995 [5]: 27 PDUs to support radio and tactical data links, simulation management, electronic warfare and laser interactions for smart munitions.
- IEEE 1278.1a-1998 (1998) [6] 67 PDUs with additional support for emissions, entity information/interaction, mine warfare, entity management, field instrumentation, communications and environment.

With each revision, the approach has been to add new capability via new PDUs with minimal changes to existing PDU structures. Thus an Entity State PDU (ESPDU) in 1278.1a - 1998 is identical to an ESPDU in 1278.1 - 1995, except for the field specifying DIS version.

The IEEE 1278-1993 standard defined 10 PDU types:

1) Entity State
2) Fire
3) Detonation
4) Service Request
5) Resupply Offer
6) Resupply Received
7) Resupply Cancel
8) Repair Complete
9) Repair Response
10) Collision

The IEEE 1278.1-1995 Standard extended the 10 DIS 1.0 PDUs giving the following 27 PDUs:

A) Entity Information
    1) Entity State PDU
B) Weapons Fire
    2) Fire PDU
    3) Detonation PDU
C) Logistics Support
    4) Service Request PDU
    5) Resupply Offer PDU
    6) Resupply Received PDU
    7) Resupply Cancel PDU
    8) Repair Complete PDU
    9) Repair Response PDU
D) Collisions
    10) Collision PDU
E) Simulation Management
    11) Create Entity PDU
    12) Remove Entity PDU
    13) Start/Resume PDU
    14) Stop/Freeze PDU
    15) Acknowledge PDU
    16) Action Request PDU
    17) Action Response PDU
    18) Data Query PDU
    19) Set Data PDU
    20) Data PDU
    21) Event Report PDU
    22) Message PDU
F) Distributed Emission Regeneration
    23) Emission PDU
    24) Laser PDU
G) Radio Communication Protocol
    25) Transmitter PDU
    26) Signal PDU
    27) Receiver PDU

2.1.1 The Entity State PDU

Information associated with the entity is communicated in a DIS exercise through the use of an Entity State PDU (ESPDU). The ESPDU includes information necessary for the receiving simulation application(s) to represent the issuing entity in the simulation applications' own simulation.

The entity information exchanged between simulation applications includes the type of entity, its location and orientation, and how the entity might appear to others.

a) *Types.* The simulation entity could be a vehicle, a building, a munition (eg. a missile), or a cloud of smoke. DIS requires that entities be classified based on their entity type, allowing a variety of different entities to be represented.
b) *Location and Orientation.* Sending the location and orientation of an entity is critical for its correct representation by other simulations on the network. Inclusion of the velocity and the acceleration parameters allows receiving simulations to employ higher-level, higher-accuracy extrapolation routines. Dead reckoning parameters are also transmitted.

c) *Appearances.* The appearance of an entity can be expressed in a number of ways. Entities may be on fire or smoking. An entity may emit engine smoke or have a wake trailing behind in the water.

2.1.2 Entity Interaction PDUs

Throughout a simulation exercise, the state information associated with the interactions that take place between entities needs to be exchanged. Interactions that are currently supported include weapons fire, logistics support, and collisions.

a) *Weapons Fire.* When an entity fires a weapon, the simulation application controlling the entity needs to communicate the location of the firing weapon and the type of munition fired. The detonation of the munition is also communicated by the simulation application controlling the firing entity. Using the information in the detonation message, all simulation applications controlling affected entities assess damage to their entities.

b) *Logistics support.* Certain services may be modelled in a simulation exercise such as resupply or repair of vehicles. These services are provided under logistics support.

c) *Collisions.* In the event that two entities collide, the simulations controlling the entities must be informed of the collision. Each simulation sends a message when it detects that its entity has collided with another entity. Each simulation determines the damage to its own entity based on information in the collision message.

2.2 Advantages of DIS

DIS provides a standard means of interconnecting simulators. Since the format of the PDU fields, together with appropriate data, has been standardised, many tools have been developed, such as scenario generators, viewers, data loggers, and analysis toolkits. One such tool, Modular Semi Automated Forces (ModSAF), is a scenario generator which is used at hundreds of sites worldwide [8]. ModSAF has been obtained by DSTO, via TTCP, and is used by several DSTO Divisions for research and development.

DIS provides a standard set of enumerations for entities and also for weapons, sensors, communication devices, environmental descriptors and other attributes. This is a highly comprehensive set that includes virtually the entire US and former Soviet inventories, as well as those of other major nations such as Germany, France and the U.K. Each country has a unique identifying enumeration: eg. Australia (13), USA (225), Russia (222). Compliance with those enumerations is mandatory for participation in a DIS exercise. The DIS enumerations listings are maintained through the Simulation Interoperability Standards Organisation (SISO) [9]. Australian enumerations are discussed at section 5.5, and SISO is discussed in detail in section 9.

DIS also specifies a standard set of dead reckoning algorithms that can be used to reduce network traffic. For example, dead reckoning algorithm 2 specifies that the entity's orientation is fixed, and its velocity constant. Network packet formats are fully defined, allowing any compatible simulator or simulation to interoperate (plug and play). In addition, there are many Commercial-Off-The-Shelf (COTS) applications (viewers, loggers, etc) that can be used.

In addition, a DIS Test Suite (DTS) has been developed (see section 7.5.2) to test DIS compliance of simulations and simulators prior to participation in DIS exercises, in an internationally accredited automated environment.

2.3 Disadvantages of DIS

Whilst a standard protocol, DIS may sometimes be viewed as rigid and inflexible. In response to this criticism, functionality has been added to DIS by creating new PDUs rather than by redesigning its architecture to provide more flexibility. The final standard contains 67 PDUs, most of which contain redundant data fields. For strict compliance to the DIS standard, however, all PDU fields should be correctly populated. This can result in high computational requirements and network bandwidth for very large scale networked systems.

DIS also has limited support for entity aggregation/deaggregration and is designed specifically for real time platform level systems such as manned flight simulators. However, these disadvantages may not be a problem where manned military simulators are being networked together as training simulators, and the bandwidth requirements can be met.

DIS code is not portable/re-usable when using a different DIS toolkit from a different toolkit supplier. In addition, DIS compliance does not necessarily guarantee interoperability. The fidelity of the models may differ significantly between participating simulators, resulting in unfair fights. Finally, DIS may lack a basic level of security because PDUs are a published standard - any player can eavesdrop the exercise on the network.

3. High Level Architecture

3.1 HLA Description

The High Level Architecture (HLA) is a methodology designed to support distributed simulation exercises [10]. It has been mandated by the **US DoD** as the replacement for both DIS and ALSP (Aggregate Level Simulation Protocol), a networking protocol used for connecting wargames [11]. HLA development is sponsored by DMSO.

HLA is defined by the rules that specify how simulations interact and the Run Time Infrastructure (RTI) that provides the means to exchange data during execution. Simulations are now called federates and a set of participating federates is known as a federation. The RTI (a software toolkit) is provided free by DMSO and can be downloaded from the Internet.

Each *federate* must have an associated Simulation Object Model (SOM) which describes its data requirements for modelling entities. The SOM has a tabular format with an object class structure table and an interaction class structure table. Object classes typically refer to simulated physical entities such as aircraft and ships while interaction classes describe the entity actions and interactions that occur in simulations such as weapon fire and communications. Each object class is characterised by a set of attributes describing its properties such as position and velocity whereas each interaction class is characterised by a set of parameters such as the result of a munitions detonation. HLA supports a hierarchical class structure although not allowing multiple inheritance.

To form a group of participating federates known as a federation, a Federation Object Model (FOM), must be developed. This FOM has the same structure as the SOMs and identifies the attributes and interactions supported by the federation.

HLA provides for interaction between different types of systems such as real-time simulations and event-stepped wargames. The RTI Time Management services (see Section 3.3) have been designed to handle interactions between both logical time and real time systems.

Whereas DIS specifies fixed formatted PDUs, HLA lets the user define what data, in what format, are required to be interchanged among federation members. Thus HLA has the potential to be considerably more efficient than DIS. Only the data required to support a federation need be sent over the network rather than the redundant data sent in the DIS PDUs. Further, HLA should only send data that has changed.

Although parts of HLA are going through the IEEE standardisation process, this is not yet complete. HLA standardisation is underway [12] – there are three draft standards (designated by the **P**)

- P1516 – Framework and rules;
- P1516.1 – Federate interface specification; and
- P1516.2 – Object Model Template.

3.2 HLA Standardisation

- ***Framework and Rules - IEEE Standard P1516***: The HLA rules describe the responsibilities of federates (simulations, supporting utilities, or interfaces to live systems) and federations (sets of federates working together to support distributed applications). The rules comprise a set of underlying technical principles for HLA.

For federations, the rules address the requirement for a Federation Object Model (FOM), object ownership and representation, and data exchange. For federates, the rules require a Simulation Object Model (SOM), time management in accordance with the HLA Runtime Infrastructure (RTI) time management services, and certain mandatory functionality and constraints on attribute ownership and updates.

- ***Federate Interface Specification - IEEE Standard P1516.1:*** In HLA, federates interact with a Run Time Infrastructure (analogous to a special-purpose distributed operating system) to establish and maintain a federation and to support efficient information exchange among simulations and other federates. The HLA interface specification defines the nature of these interactions, which are arranged into sets of basic RTI services.
- ***Object Model Template (OMT) Specification - IEEE Standard P1516.2:*** The HLA requires simulations (and other federates) and federations to each have an object model describing the entities represented in the simulations and the data to be exchanged across the federation. The HLA object model template prescribes the method for recording the information in the object models, to include objects, attributes, interactions, and parameters, but it does not define the specific data (e.g., vehicles, unit types) that will appear in the object models.

3.3 RTI Services

The RTI's primary function is that of a data distribution mechanism. Federates send information through the RTI, which distributes the information to the appropriate parties. The RTI does not maintain information about the state of the federation nor does it handle any semantics associated with the interaction between the federates, such as what coordinate system to use, what happens during a collision, or how to dead-reckon remote vehicles. Also, the RTI does not specify the exact byte layout of data sent across the network.

The RTI provides a common set of services to the federates. They can be divided into six categories:

1. *Federation Management:* Handles the creation, dynamic control, modification, and deletion of a federation execution.
2. *Declaration Management:* Enables federates to declare to the RTI their desire to generate (publish) and receive (subscribe/reflect) object state and interaction information. Federates can subscribe to only the objects they want (or have the capability) to receive, e.g. tanks might need only data pertaining to ground movement, or airplanes might need only data pertaining to flight activities
3. *Object Management:* Enables the creation, modification, and deletion of objects and interactions. These services comprise most of the network traffic during runtime.
4. *Ownership Management:* Allows federates to transfer ownership of object attributes to other participants in the simulation.
5. *Time Management:* Provides useful services for setting, synchronizing, and modifying simulation clocks. Time Management services are tightly coupled with

the Object Management services so that state updates and interactions are distributed in a timely and ordered fashion.

6. *Data Distribution Management:* Federates can provide conditions governing when to start or stop transmitting and receiving certain pieces of data.

The first four of these broadly provide similar functionality to the DIS Entity Information, Entity Management, and Simulation Management PDUs although with a superior architecture. The Time Management and Data Distribution Management services have no equivalence in DIS which implicitly assumes real time interaction among time-synchronised systems and a broadcast mechanism for data distribution. These RTI services provide advantages over traditional DIS.

3.4 Advantages of HLA

HLA attempts to overcome the deficiencies noted with DIS, with the federation members defining in advance what data need to be sent to the network via HLA's publish/subscribe mechanism. It also provides greater functionality - any attribute can be dead reckoned and any logical coordinate system can be used instead of the 3D DIS geocentric system.

HLA supports both real time and logical time management. It also allows entity aggregration and deaggregration. This enables interaction between both virtual and constructive simulations that may use non real time and employ aggregrate units such as battalions rather than single platforms.

The main advantage of HLA is that it reduces the required bandwidth, since only the required data is transmitted. In addition, further reductions in bandwidth use are possible since users have the freedom of defining when attributes should be updated.

A further advantage of HLA is that since data broadcast is FOM-specific, it will have an automatic level of security: interested parties will not be able to interpret these data on the network without knowledge of the FOM data content and formats.

3.5 Disadvantages of HLA

As discussed, HLA is far more flexible than DIS - however this flexibility can also be its weakness: unless all federates agree on a FOM they will not be able to interoperate even though they are HLA-compliant. Thus HLA compliance will not guarantee interoperability, due to the requirement to agree on a specific FOM beforehand.

Each FOM needs its own separate set of enumerations which are provided as standard in DIS. Dead reckoning algorithms must be developed as required instead of using the standard DIS set. Moreover, since each FOM will be unique, FOM-specific viewers, loggers, and analysis toolkits must be developed. Such tools are not presently available as COTS software, and must be individually created.

Due to FOM dependence, HLA compliance will not guarantee that two simulators can talk to each other. To use an analogy between simulation interoperability and normal human communication: with DIS all systems speak the same language, eg. English, with the same vocabulary and syntax. In contrast, extending the analogy, HLA compliance will only mean that each system has agreed to use spoken language for communication, so one system will use English, another Russian etc. Each system will be sending HLA packets, or words in the human communications analogy, but these packets will be formatted differently. An English speaker and a Russian speaker each use spoken language but cannot communicate (interoperate) because of language differences.

The need for *Reference FOMs* has been proposed to assist with conversion of systems to HLA and to further promote interoperability. The Real-Time Platform Reference FOM (RPR-FOM) has been developed for real-time platform level federations to facilitate the transition for DIS compatible simulations to HLA [13]. The RPR-FOM is a HLA description of the DIS protocols. It will eventually support the functionality contained in DIS 2.1.4 (the final standardised version of DIS) and is supplied with both the MaK VR-Link toolkit and the Institute of Simulation and Training (IST) DIS/HLA Gateway (see section 4.1). It is also a Simulation Interoperability Standards (SISO) standard (see section 9). However, the RPR-FOM, which maps the DIS PDUs to HLA, currently supports DIS 2.0.4 only, and will not support DIS 2.1.4 until at least late 2000.

It should be noted that HLA compliance testing involves testing against one's own system – the only system **guaranteed** to be interoperable.

3.6 General Issues with DIS and HLA

Commonality of the synthetic environment is a fundamental requirement for distributed simulation. However neither DIS nor HLA ensures correlation of the different databases. One approach with HLA [14] is to develop a run-time terrain component interface that allows a simulation to use the terrain database independent of the actual terrain representation.

Voice and Data link communications can be achieved in DIS using the Radio Communications PDU family. HLA implementations will need to develop communications classes to achieve the same functionality.

4. Migration to HLA

Increasing demands are being put on legacy simulators to upgrade to HLA. For example, the USN is considering migration options for its legacy Battle Force Tactical Training (BFTT) Program from DIS to HLA [15]. However, HLA remains a developing standard (and technology) and to be interoperable with current Commercial-Off-The-Shelf (COTS) products, DIS compliance is still required.

Because of the US DoD's mandating of HLA, considerable effort has been applied to provide a means of enabling DIS-compliant systems to upgrade to HLA. Migration of DIS to HLA is available via:

a) a gateway which translates between DIS PDUs and HLA Services in both directions in real-time [16];
b) middleware which resides in the simulator [17]; or
c) native HLA integration which entails software redesign to conform to the HLA requirements [18].

Each approach has associated costs and risks as discussed below. These approaches have been previously outlined for the Royal Australian Navy with respect to Project Sea 1412 [19].

4.1 DIS / HLA Gateway

A DIS/HLA *gateway* converts between DIS PDUs and HLA Services in both directions in "real-time" whilst the simulation exercise is in progress. This is the easiest way to implement HLA compliance, as there is no modification required in the DIS compliant legacy simulator other than placing the gateway "box" between the legacy simulator and the HLA network. However, it is likely to result in the greatest additional latency. Where the benefits of HLA (interaction with constructive simulations, reduced broadcasting of data, etc) are not required, the gateway remains the most effective way to retain the benefits of interoperability by DIS, whilst still having the ability to connect via HLA.

One example of a DIS/HLA Gateway, from the Institute of Simulation and Training (IST), provides a path for legacy systems to interoperate with HLA federations using the RPR-FOM [20]. The Gateway is a stand-alone interface node connecting DIS (2.0.3, 2.0.4, IEEE 1278.1, IEEE 1278.1a) networks to an HLA RPR-FOM federation execution. No modification of the existing legacy system is required because the Gateway is stand-alone. On the DIS side of the Gateway, PDUs are formatted, sent, and received according to the protocol. The Gateway receives these packets and translates them at two levels: (1) the DIS PDU data packets are converted into the data formats defined in the RPR-FOM, and (2) the sequence of packets are translated into corresponding RTI service invocations.

The Gateway performs a similar conversion of data received from the HLA federation execution. The Gateway must also perform those functions for which there are no DIS analogues. These functions include creating, destroying, joining, and resigning federations and publishing and subscribing to the RPR-FOM classes.

4.2 Middleware Approach

In the *middleware* approach, the application uses a higher level (abstraction) interface, which can be used for both DIS and HLA services. Since the topmost HLA software layer works in parallel with, or replaces, the equivalent DIS software layer, latency is reduced compared to the gateway option.

MäK Technologies' VR-Link now supports both DIS and HLA (using the RPR-FOM) [7]. If VR-Link is already being used, HLA/DIS support is selected via a compile time switch and minimal change to a simulator's source code. Utilising this toolkit for HLA compliance is an attractive proposition because VR-Link is already widely used in the simulation industry and much of the DIS/HLA code maintenance is indirectly shifted to MäK Technologies.

4.3 Native HLA Integration

A *native* integration is a tight coupling between the HLA and simulator code. Throughout the simulator the DIS paradigm is replaced by the more modern, object oriented, philosophy of HLA. This approach should provide all the benefits of HLA but at the highest initial and continuing cost. Since the interface code is FOM dependant, considerable software development and associated maintenance will be required, and backward DIS compatibility is unlikely unless a FOM similar to the RPR-FOM is used.

5. DIS/HLA for ADF Simulation Projects

The Australian Defence Force is essentially presented with the choice between DIS and HLA as the means to provide simulator interoperability. Each project is essentially considering the way ahead with respect to DIS/HLA on a case by case basis. The formation of an Australian Defence Simulation Office (ADSO) and the promulgation of an Australian Defence Simulation Master Plan, will shortly provide improved guidance. Both the ADF and DSTO are developing distributed simulation projects. Two of the flagship projects for Navy and Air Force are described below.

5.1 Maritime Warfare Training System Project

Through Project SEA 1412, the RAN is seeking to develop the Maritime Warfare Training System (MWTS) which will initially link several existing operations room trainers to provide enhanced command team and tactical training for the RAN into the 21st century [21].

In later phases of the Project, an Australian wide-area maritime simulation network will be established. This system could include ships alongside at Fleet Base East in Sydney and Fleet Base West in Western Australia, linked via their on-board training

systems with the wargaming system and ship models at HMAS WATSON in Sydney, as well as other ADF simulators, such as RAN helicopter simulators and RAAF P3C, FA-18 and Airborne Early Warning & Control (AEW&C) simulators, all participating in a common virtual scenario. In time, there is potential to extend this environment to include ships at sea, although this requirement will create various communication challenges.

This will provide training for the two-ocean based Navy (Sydney and Perth) without requiring expensive co-location of assets. The MWTS would provide manned assets, instructor supervision, and game control and debriefing, for exercises involving both live and simulated assets across a large synthetic operating area. The Maritime Warfare Training System is depicted in Figure 1.

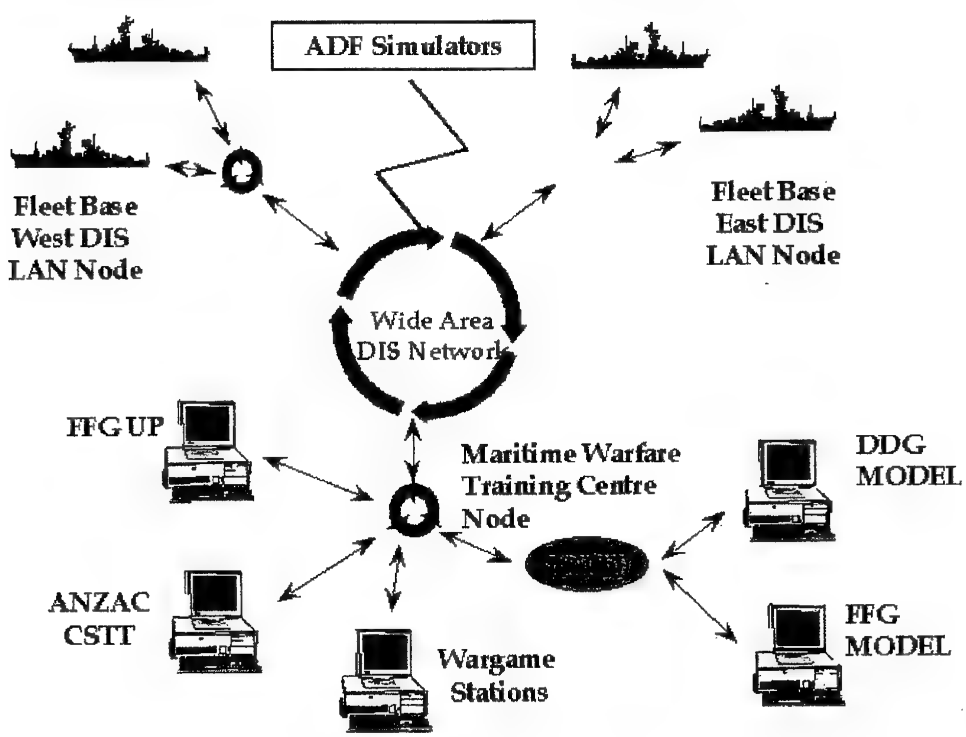

Figure 1: Maritime Warfare Training System

During later stages of the development of the MWTS, DIS connectivity would also allow linkages to other DIS-enabled Australian Defence Force (ADF) simulators such as the Seahawk simulator and P3C simulator (as examples), to participate in larger scale combined exercises over a wide area network (WAN) on an opportunity basis. Further

in the future a DIS capability will enable the RAN to participate in international simulated exercises.

DIS/HLA interfaces are required for the components that will make up the MWTS. Considering:

a) the immaturity of HLA;

b) that an upgrade path to HLA can be achieved via appropriate software; and

c) the maturity of DIS;

it is expected that DIS will be implemented for the first Phase which comprises a Local Area Network at HMAS WATSON with a number of participating simulators.

The US Navy is developing the Battle Force Tactical Training (BFTT) system that uses distributed simulation to provide training for individual and multiple sets of ships. BFTT is primarily an in-port, shipboard, combat system team training capability that operates by stimulating/simulating shipboard sensors and by introducing virtual forces such as friendly, neutral and hostile aircraft, ships and submarines.

It is essential that SEA 1412 be able to interoperate with BFTT to enable matritime coalition training in a synthetic environment. BFTT is using DIS (rather than HLA), thus SEA 1412 will use DIS and in conjunction with the BFTT program, move to HLA when appropriate. At such a later stage, HLA capability could be added to allow interoperability with external HLA-compliant systems. Thus later phases of the MWTS may run DIS internally on the HMAS WATSON LAN and communicate externally via HLA. DSTO (AOD) is cooperating with the USN BFTT program in outlining a collaborative research program on issues associated with migration from DIS to HLA [22].

A similar approach could be adopted for the On Board Training Systems (OBTS) which will be added to the MWTS. By specifying a DIS/HLA interface for the OBTS, appropriate interfacing software can provide either DIS or HLA as needs require.

5.2 Virtual Air Environment

The 1997 Defence White Paper placed a high priority on the ability to integrate surveillance and intelligence information to detect, track and identify all air and maritime targets in Australia's northern approaches. A number of systems (JORN, AEW&C, Air Defence Ground Environment (ADGE), and the Air Command Support Systems (ACSS) are being acquired to meet the air surveillance/airspace control/air defence component of this capability.

Introduction of JORN, AEW&C and a modern ground control environment will require a considerable increase in the number of active Air Defence Controllers. However, the number of F/A-18 missions available to support ADCON training will remain static. The significant investment in Air Defence and Airspace Control systems

must be supported by comprehensive simulation systems if operators are to maintain at an acceptable level of operational capability.

The Virtual Air Environment (VAE) Project aims to provide a framework within which many RAAF training simulation activities would take place [23]. The VAE concept would have applicability to a wide range of ADF simulation systems, to the evaluation of operational capabilities, and to the development and analysis of C4I and weapons systems.

The VAE concept is based on the stimulation of, and embedded simulation within, the Air Defence and Airspace Command, Control and Communication System (ADAC2S), which will be operational in the year 2001. The VAE could also be linked to Army and Navy simulation systems to provide a common environment for future joint simulation activities.

The Initial Development Phase of the VAE project focuses on an application to Air Defence Controller training, which integrates real assets (RAAF Williamtown Air Defence Controller Consoles) and virtual simulations (comprising Human-in-the-Loop (HiL) and computer generated entities) in one environment, to create a cost-effective virtual world training capability. Eventually, this could involve most of the Australian Air Defence System. DIS is being used initially as the networking protocol.

Figure 2 shows the linkage between the Air Operations Division in Melbourne (supplying HiL simulators and CGFs) and the Number 3 Control and Reporting Unit (3CRU) based at RAAF Base Williamtown. In the first VAE demonstration [24] the virtual world was generated at DSTO's Air Operations Simulation Centre (AOSC) at Fishermens Bend, Melbourne. The AOSC was connected to RAAF Williamtown via an ISDN Wide Area Network. Virtual entities generated at the AOSC were correctly observed in the RAAF Williamtown radar system.

This demonstration involved linking four systems: a human-in-the-loop F/A-18 flight simulator, two sources of computer generated entities (BattleModel and STAGE), and the operational Phoenix display system for Air Defence Controllers. The first three provide computer-generated entities that stimulate the operational Air Defence System to provide command and control training.

An Air Defence Controller, using the real Air Defence System at Williamtown, directed the pilot of the F/A-18 flight simulator in Melbourne to intercept virtual (computer generated) entities also produced in Melbourne. All entities were displayed on the real Air Defence Controllers' display system in Williamtown.

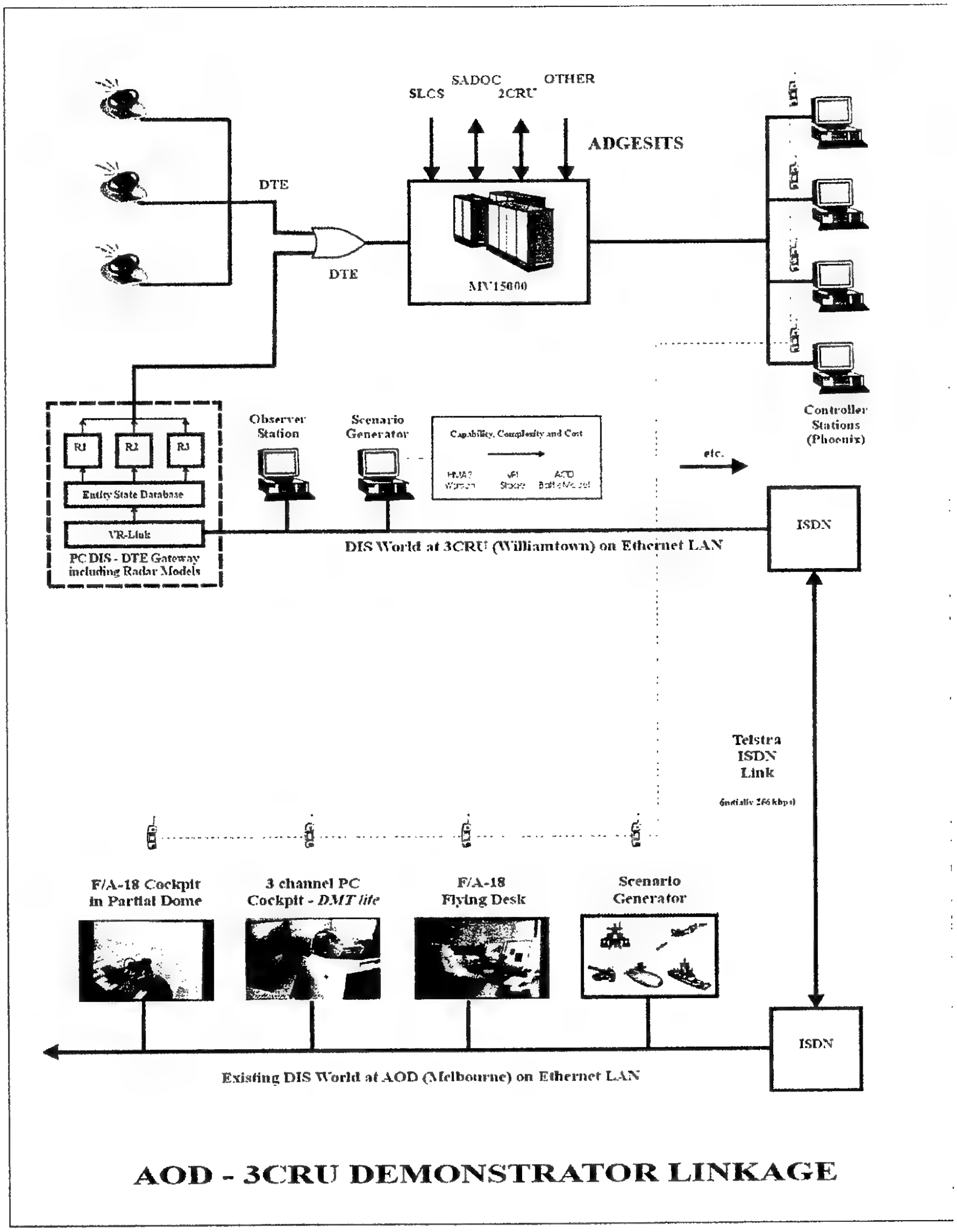

Figure 2: *The linkage between the Air Operations Division in Melbourne (supplying HiL simulators and CGFs) and the Number 3 Control and Reporting Unit (3CRU) based at RAAF Base Williamtown.*

5.3 DSTO's Virtual Ship Project

DSTO's Maritime Operations Division is co-ordinating a DSTO-wide R&D project to develop the Virtual Ship [25]. This project employs HLA as the core technology to connect modelled ship subsystems such as sensors, weapons, and C2 systems into an integrated simulation of a naval vessel. Potential applications of the Virtual Ship include capability development, acquisition, training, mission rehearsal and tactical development. HLA compliant simulation models of sensors, weapons and command and control system components are currently under development.

The Virtual Ship Architecture Working Group (VSAWG) is developing the Virtual Ship Architecture (VSA), which is based on HLA. As is required by HLA, significant effort has been devoted to architectural design, with emphasis on the construction of the Virtual Ship Federation Object Model (VS-FOM). Another critical aspect of the VSA is the concept for federation execution management, and a first version of the Virtual Ship Execution Manager (VSEM) is nearing completion.

5.4 Synthetic Environment Research Facility

DSTO's Land Operations Division has established the Synthetic Environment Research Facility (SERF) at Salisbury in South Australia. Synthetic environments were built at RAAF Base Tindal, creating virtual cockpits with aircrew controls, instrumentation, visuals, communications and data capture. This was supported by the creation of a virtual terrain and scenario generation integrated into real exercises. Army crews flew (Exercise Phoenix) a number of simulated armed reconnaissance helicopter missions, as a learning exercise, resulting in significantly faster time-to-air capability while flagging critical issues.

The SERF is playing a crucial role in the support Project Air 87 – the Australian Army's latest capability acquisition program – and the development of an Armed Reconnaissance Helicopter (ARH) capability. Using the SERF for virtual exercising, the Army is gaining vital information on ARH capability before delivery of the new aircraft in 2004.

5.5 DSTO's EXC3ITE Project

The Experimental C3I Technology Environment (EXC3ITE) Project is producing an enabling environment for experimentation with new technology and work practices to assist the ADF in improving its command and control and in evolving an enhanced C4ISR capability [26]. At the core of EXC3ITE is a high-bandwidth ATM network. Various services will reside on the network designed to deliver capability to the users. The primary technology being demonstrated is the use of component architectures and object brokered services that promise to allow a more flexible and integrated solution to the development of end-user tools and applications.

EXC3ITE will provide various services mostly related to command and control applications. It will also include a set of services for simulation [27] such as:

- *Repositories* of simulation-related material such as: terrain datasets (for virtual and constructive systems); visual/IR models of entities; flight models; command agents; latency and packet-analysers; datasets, for example, platform characteristics; various information and reference sources; lessons learnt etc.
- *Stimulation services* to be used to stimulate a simulation with recorded data. The data source could be either live (tracks, weather, atmospheric/oceanic propagation conditions, sea-state etc.) or simulated from prior experimentation with the capability to manipulate the data time base and stimulate at appropriate rates.
- *Immersive synthetic environments* constituting interactive systems of systems, potentially including human-in-the-loop.
- *Translation services* such as coordinate converters; DIS to/from HLA; tracks to/from HLA; suitably broad-based or simulation-service-recommended FOMs; RTI Interface Definition (RID) files etc.

EXC3ITE will create a prototype Joint Synthetic Environment that could link existing and emerging environments such virtual air, land and maritime platforms; C4ISR, EW and Information Organisation (IO) simulations developed in DSTO, industry and by our allies through the use of interoperable standards.

5.6 DSTO Simulation Hub

DSTO is in the process of setting up a Simulation Hub. The Hub will provide Simulation researchers with a comprehensive picture of DSTO Simulation research, rather than the more specialised snapshots seen within any one Division. It provides the opportunity to be part of the wider Simulation community in DSTO and in Australia.

The primary role of the Simulation Hub will be to advise Division Chiefs on

- strategic planning of Simulation research in DSTO
- the derivation of a DSTO Simulation Plan;
- coordination of DSTO Simulation policies, plans and activities within broader Defence Simulation policies, plans and projects;
- the ER&D plan, major Simulation equipment and facility plans;
- the coordination of Simulation research efforts across DSTO Divisions and to bring wider scientific expertise to bear on difficult problems;

It will have a secondary role to:

- provide visibility of the different Simulation research areas (Focus Areas) across the entire Simulation R&D Program.
- facilitate the exchange of ideas and concepts in Simulation and related fields;
- maintain the scientific excellence of Simulation research by peer review;

- enhance the interaction between Simulation researchers at DSTO and those in the ADF, TTCP Groups, Industry, Australian Universities, and CSIRO;
- maintain and develop the DSTO Simulation skill base and provide a broader base for career development of DSTO staff working in Simulation related research;
- promote the incorporation of Simulation Requirements Specifications at all stages of the Defence acquisition process.

5.7 Other ADF Projects

Whilst the MWTC and VAE are overarching ADF projects for the maritime and air defence environments, other ADF projects are developing systems capable of being linked to these virtual environments. The Army is developing vehicle simulators, Navy is developing and upgrading various helicopter simulators and the OBTS for its FFGs, whilst Air Force is upgrading its flight simulators to include interoperability via DIS/HLA.

5.8 Australian Military Platforms Included in SISO DIS Enumerations

At the request of Australia (Air Operations Division, DSTO), SISO updated (in 1998) the DIS enumerations to include the six Australian Guided Missile Frigates (FFGs), three Charles F. Adams Destroyers (DDGs) and two Oberon class submarines. These assets were designed and/or built overseas and must be included under the country to which a particular platform's design is attributed according to the DIS 1278 IEEE standard.

5.8.1 FFG and DDG Enumerations

The FFGs and DDGs are now included under the US asset listings with Australian designations as listed in Table 1.

Table 1: Enumerations for Australian DDGs and FFGs

Vessel Class	Vessel	Enumeration	Descriptor
DDG	HMAS Perth	1-3-225-4-5-1	DDG Perth (Australia)
	HMAS Brisbane	1-3-225-4-5-2	DDG Hobart (Australia)
FFG	HMAS Adelaide	1-3-225-6-1-1	FFG 01 Adelaide (Australia)
	HMAS Canberra	1-3-225-6-1-2	FFG 02 Canberra(Australia)
	HMAS Sydney	1-3-225-6-1-3	FFG 03 Sydney (Australia)
	HMAS Darwin	1-3-225-6-1-4	FFG 04 Darwin (Australia)
	HMAS Melbourne	1-3-225-6-1-5	FFG 05 Melbourne (Australia)
	HMAS Newcastle	1-3-225-6-1-6	FFG 06 Newcastle (Australia)

The enumeration is interpreted as follows for HMAS Adelaide:

- Kind – 1 for platform
- Domain – 3 for surface
- Country – 225 for US (country of design)
- Category – 4 for guided missile frigate
- Subcategory – 1 for Oliver Perry class
- Specific – FFG01 Adelaide (Australia)

Note that a new subclass, Modified Charles F. Adams, was created to incorporate the Australian DDGs. The US Navy no longer has any Charles F. Adams class DDGs in service.

5.8.2 Oberon Submarine Enumerations

Similarly, the two remaining in-service Oberon class submarines are included under the UK assets as:

Oberon Submarines:
1-4-224-5-2-60 Onslow (Australia)
1-4-224-5-2-62 Otama (Australia)

5.8.3 Other Australian Enumerations

For Air Force, AOD had previously included the Nomad aircraft type (no longer in service). These enumerations are listed in Table 2. Other RAAF assets such as the F/A-18 and F111 are US-designed and do not require distinct enumerations. As new Australian platforms (eg A-P3C and AEW&C aircraft) are acquired, specific DIS enumerations will need to be assigned.

Table 2: Enumerations for RAAF assets

Kind	Domain	Country	Category	Subcategory	Specific
1	2	13	4 (Cargo/Tanker)	0 (other)	
				1 (GAF Nomad)	1 N22B 2. N24A

In 1995, Australia (through AOD, DSTO) submitted and had included the enumeration and bit-encoded values of Australian built vessels such as ANZAC class frigates and Collins class submarines. These assets are identifiable by using the Country enumeration (code 13 for Australia). This will assist the Royal Australian Navy with clear identification of assets for Project SEA 1412, and will allow future participation in combined synthetic exercises. New Zealand vessels HMNZS Te Kaha and HMNZS Te Mana, built by Australia, will also need to have unique enumerations allocated.

Enumerations for surface warfare, mine warfare, and submarines are included in Tables 3, 4, 5, respectively.

Table 3 Enumerations for RAN surface warfare vessels

Kind	Domain	Country	Category	Subcategory	Specific
1	3	13	6 (Guided Missile Frigate) FFG	0 (other)	
				1 ANZAC Class (Meko 2000)	FFG 150 Anzac FFG 151 Arunta FFG 152 Warumungu FFG 153 Stuart FFG 154 Parramatta FFG 155 Ballarat FFG 156 Toowoomba FFG 157 Perth
			7 Light/Patrol Craft	0 Other	
				1 Fremantle Class (Large Patrol Craft)	1 P 203 Fremantle 2. P 204 Warrnambool 3. P 205 Townsville 4. P 206 Wollongong 5. P 207 Launceston 6. P 208 Whyalla 7. P 209 Ipswich 8. P 210 Cessnock 9. P 211 Bendigo 10. P 212 Gawler 11. P 213 Geraldton 12. P 214 Dubbo 13. P 215 Geelong 14. P 216 Gladstone 15 P 217 Bunbury
			50 Frigate	0 Other	
				1 River Class (FF)	

Table 4 Enumerations for RAN mine warfare vessels

Kind	Domain	Country	Category	Subcategory	Specific
1	3	13	8 Mine Countermeasure Ship/Craft		
				0 Other	
				1 Huon Class (Minehunters-Coastal)	1 M 82 Huon 2 M 83 Hawkesbury 3 M 84 Norman 4 M 85 Gascoyne 5 M 86 Diamantina 6 M 87 Yarra
				2 Bay Class (Minehunters - Inshore)	1 M 80 Rushcutter 2 M 81 Shoalwater
				3 COOP class minesweepers (auxiliary)	1 1102 Brolga 2 1185 Koraaga 3 Y 298 Bandicoot 4 Y 299 Wallaroo

Table 5: Enumerations for RAN Collins Class Submarines

Kind	Domain	Country	Category	Subcategory	Specific
1	4	13	4 SSG (Conventional Guided Missile)	0 Other	
				1 Collins Class	1 S 71 Collins 2 S 72 Farncomb 3 S 73 Waller 4 S 74 Dechaineux 5 S 75 Sheean 6 S 76 Rankin

5.8.4 Other Enumerations Required for DIS Compliance

In addition to the platforms, enumerations in DIS are required to describe:

- Munitions
- Life forms
- Environmental features
- Cultural features
- Supply descriptors
- Radios
- Expendables
- Sensors and Emitters

These will also need to be included in the DIS enumeration database for compliance with the DIS standards. For example, the sonar enumerations are sparsely populated compared to the radar enumerations since underwater warfare was not allowed for until the latest version of DIS. Enumerations for sonar systems attached to RAN ships will need to be included for full compliance with DIS.

6. Further DMSO Initiatives

DMSO has initiated several other programs to simplify the modelling and simulation process. Similarly to HLA, these programs are aimed at promoting interoperability, software reuse, and standardisation. These are generally less developed than the HLA initiative. The most relevant of these to Australian Defence are discussed in the following sections.

6.1 SEDRIS

Common representation of the physical environment is a necessary precondition for interoperability in heterogeneous modelling and simulation (M&S). The level of interoperability achieved depends heavily upon the degree of consistency, completeness and unambiguous definition of environmental data. No uniform and effective standard mechanism currently exists for describing, re-using, and

interchanging environmental data among M&S applications. Additionally, data sharing rarely occurs between the operational and simulation communities, although each community uses representations of the same physical aspects of the real world.

The Synthetic Environment Data Representation and Interchange Specification (SEDRIS) Project [28] is an R&D effort focused on providing a pre-runtime interchange mechanism supporting the distribution of source data, three-dimensional models and integrated databases that describe the physical environment. The capability to share common descriptions of the physical environment through a standard interface is a precondition for interoperability.

SEDRIS is a DMSO funded activity to develop a robust capability for environmental data interchange. The disparate nature of simulation interests in environmental data must be accounted for, as must the wide variety of environmental data types required to populate a sufficiently complete representation of the physical world to meet M&S Community objectives.

Support for the operational domains of land, sea, air, and space is required in the arenas of live, virtual, and constructive simulation. There is concern for the common use of environmental representations in a wide variety of national and international Defence and Commercial systems. The SEDRIS Interchange Mechanism will eliminate data stovepipes by addressing total of existing and anticipated data interchange requirements, rather than their lowest common denominator intersection.

6.1.1 SEDRIS Technical Components

SEDRIS developers have now defined all the technical components of the interchange mechanism:

- **Common Data Representation Model (DRM)** - removes ambiguity by ensuring that all types of environmental data are captured, and relationships between alternate representations (eg. feature versus geometry) defined. It contains object-oriented documentation, in two versions, enhanced Rumbaugh notation, and Unified Modeling Language (UML).

- **Interface Specification**: Documentation defines a consistent interface between a user's (either a data provider or a data consumer) software application and SEDRIS transmittals. The API decouples the user's application from the transmittal's data structures, allowing the data representation model, its transmittal mechanism-specific data structures, and the user's application to evolve relatively independently of each other. Reference implementations of both a read and write API, with supporting libraries, have been developed.

- **SEDRIS Transmittal Format (STF)** provides a platform-independent data interchange format for SEDRIS transmittals. Its file format defines the organisation of a persistent SEDRIS format. Further documentation is available [28].

- **Environmental Data Coding Specification (EDCS)** provides a classification, attribute, and state data-coding standard. This allows enumeration to be separated from both the data model and the data dictionary for greater flexibility and enlargement. EDCS is available as a database in Access form.

- **Spatial Reference Model (SRM)** defines the specification of co-ordinates, projections, and a variety of spatial reference systems as used in SEDRIS interchange.

6.1.2 SEDRIS Objectives and Deliverables

SEDRIS objectives are:

a) to articulate and capture the complete set of data elements and associated relationships needed to fully represent the physical environment.;
b) to support the full range of simulation applications (eg. computer-generated forces; manned, visual and sensor systems) across all environmental domains (terrain, ocean, atmosphere and space); and
c) to provide a standard interchange mechanism to pre-distribute environmental data and promote database reuse and interoperability among heterogeneous simulations.

SEDRIS deliverables will be:

a) Common data representation model and associated data dictionary. The data model will remove ambiguity by ensuring that all types of environmental data are captured and relationships between alternate representations (eg. feature versus geometry) defined.
b) Interface Specification. This will provide a consistent interface between a user's (either a data provider or a data consumer) software application and SEDRIS transmittals. The API decouples the user's application from the transmittal's data structures, allowing the SEDRIS Data Model, its transmittal mechanism-specific data structures, and the user's application to evolve relatively independently of each other.
c) SEDRIS Transmittal Format (STF). The STF provides a platform independent data interchange format for SEDRIS transmittals. It is a file format that defines the organisation of a persistent SEDRIS format.
d) Data Coding Standard. The SEDRIS Project has developed a classification, attribute, and state data-coding standard. This allows enumeration to be separated from the data model and dictionary for greater flexibility and extensibility.
e) Spatial Reference Model (SRM). The SRM fully defines the specification of co-ordinates, projections, and a variety of spatial reference systems as used in SEDRIS interchange.

f) Associated Tools and Utilities. A set of software tools and utilities, based on the SEDRIS Interface Specification, has been developed to aid in viewing, examining, and validating elements of a SEDRIS transmittal.

6.1.3 Standardisation of SEDRIS

SEDRIS Technology will soon begin a formal review process towards international standardisation. This process will include all technical components as well as extend the marketplace for SEDRIS use. SEDRIS components will be assessed for international use within Defence, other Government, industry, and academic applications. Standards quality documents are being prepared, as is documentation supporting SEDRIS formal referencing in the DoD Joint Technical Architecture and in procurement directives. The primary standard for SEDRIS core technology will be comprised of three parts:

- Part 1: SEDRIS functional specification
- Part 2: SEDRIS abstract file format
- Part 3: SEDRIS file format binary encoding

Part 1 will specify semantics and abstract syntax based on the SEDRIS data representation model, along with associated data types and elements of the format. It will also contain a functional description of the interface specification (both the Read API and the Write API).

Part 2 will contain an abstract description of the file format sufficient to lay down the ground rules for encoding this file format. It will describe how the file format is organised and how the functionality and data model described in part 1 is to be supported in a file.

Part 3 will be a binary encoding of the abstract description contained in Part 2. The rules in Part 2 and the definitions in Part 1 will be mapped to physical values and physical data types, and a SEDRIS Language Bindings multi-part standard initiated. The Read API and Write API, with functional descriptions contained in Part 1 of the core standard, need to be mapped to real programming languages. The language mappings that have been assigned are Fortran 77, Pascal, Ada, C, and Fortran 90.

Language bindings are required to map the abstract data types and function interfaces defined in Part 1, to the constructs defined by the International Standards Organization (ISO) standard for the programming language in question. The C language mapping will comprise the initial work effort. Along with preparation of these standards documents, the SEDRIS Technical Documentation Set is being completed. All documents will be available to SEDRIS Users from the SEDRIS Project at http://www.sedris.org

6.2 Conceptual Models of the Mission Space

Simulation developers need a clear picture of what they wish to represent to produce a workable model or simulation. This picture will be multi-dimensional and must include a depiction of the entities, actions, and interactions. When fully defined, such a resource will provide an evolvable and accessible framework of tools and resources for conceptual analysis. There will be several Conceptual Models of the Mission Space (CMMS) [29] corresponding to broad mission areas such as conventional combat operations, other military operations, training, acquisition and analysis. The mission space structure, tools and resources, will provide an overarching framework. They will also ensure access to the necessary data and detail to permit development of consistent, interoperable, and authoritative representations of the environment, systems, and human behaviour in simulations.

6.2.1 US DoD Implementation of CMMS

As part of the US DoD M&S Master Plan (MSMP), the US DoD must develop CMMS to provide a basis for the development of consistent and authoritative simulation representations. DMSO is leading a US DoD-wide effort to provide an integrated framework and toolset for developing the CMMS. The CMMS, which provides simulation-independent warfighter descriptions of real-world processes, entities, environments, implementation and relationships, is composed of four primary components:

- conceptual models: consistent representations of real-world military operations,
- technical framework: standards for knowledge creation
- common repository: a database management system (DBMS) for registration, storage, management and release,
- library toolset: a suite of tools to browse, locate, export and report features for accessing and using mission space models data

CMMS are simulation implementation-independent functional descriptions of the real world processes, entities, and environment associated with an articulated set of missions. In particular, they provide:

- a disciplined procedure by which the simulation developer is systematically informed about the real world problem to be synthesized;
- a set of information standards the simulation subject matter expert employs to communicate with, and obtain feedback from, the military operations subject matter expert;
- the real world, military operations basis for subsequent, simulation-specific analysis, design, and implementation, and eventually verification, validation, and accreditation/certification;
- a singular means for establishing re-use opportunities in the eventual simulation implementation by identifying commonality in the relevant real world activities; and

- a library of re-usable conceptual models for simulation development.

6.2.2 CMMS for Australia

To promote code and model reuse, and to be interoperable with our major allies, Australia will also need to define CMMS for our M&S requirements, hence providing a standardised description for ADF entities, operational environments and tactics for each service need. Such an effort should be coordinated through the ADSO with appropriate input from the military customer and DSTO. Exact implementation of CMMS for Australia (and level of detail required) will need further investigation, and should be outlined in any future Defence M&S Master Plan.

6.3 Master Environment Library

DMSO has developed a Master Environment Library (MEL), which is an on-line Web-based service (http://mel.dmso.mil). The MEL serves as a repository for direct and timely access to models, algorithms, data, and products for all environmental domain areas - ocean, terrain, air and space.

Natural environment data reside at individual resource sites worldwide. These data consist of static features, dynamic features, characteristics, and phenomena of the terrain, ocean, air, and space, as well as selected permanent and semi-permanent geospatial features such as roads, bridges, buildings, cities, seaports, and airports.

The mission of MEL is to provide direct and timely access to natural environment information, data, and products, wherever they reside. This includes non-geospatial data such as models, algorithms, and documents, as well as basic environmental data. MEL is currently focused on US DoD modelling and simulation users, but is accessible to other DoD, federal, commercial, and academic communities as well.

For the warfighters, MEL supports a common interoperable view of the battlespace for mission planning, rehearsal, and execution. MEL supports modelling and simulation for training, analysis, and acquisition, thereby helping to streamline and optimise these processes.

The goal of MEL is to become the "One-Stop Environment Shop", where users can remotely access and request environmental resources. MEL provides a digital metadata database plus a universal interface that together enable a user to browse descriptive metadata through a single web site.

Any requirment for an Australian equivalent of MEL will need further investigation, and should be outlined in any future Defence M&S Master Plan.

7. Verification, Validation and Accreditation

The Military Operations Research Society (MORS), has defined the key elements in establishing a model's credibility as verification, validation, configuration management and accreditation, namely:

Verification – the process of determining that a model implementation accurately represents the developer's conceptual description and specifications. Does your model do what you think it does? Does it do the 'right thing'?

Validation – the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model. Just how good is the model? Does it do the things right?

Configuration Management – the application of technical and administrative oversight and control over the model. Which version of the model you have?

Accreditation – an official determination that a model is acceptable for the specific purpose. Is the model good enough for the application for which you want to use it?

These definitions are now widely accepted in the M&S community. A full step-by-step guide to implementing VV&A is available from the US DoD, Joint Accreditation Support Activity [30].

7.1 VV&A Descriptions

Verification amounts to an inspection of the M&S system and its documentation to determine if a given set of requirements (those from either the original development or some using activity's) are captured correctly throughout the design, implementation, test and documentation. In addition to testing for functional or standards requirements it is necessary to ensure traceability, so that all functions are captured correctly (according to specifications).

A Requirements Traceability Matrix (RTM) is often used in system development to record (in a relational database) where each requirement is satisfied in documentation, in code or hardware, in the test plan/procedures. Wherever an RTM has been maintained, verification is greatly simplified. Verification, to be affordable and effective, should be performed on a priority basis.

Validation comprises examination both of the underlying algorithms, structure, data, limitations, and assumptions; and of their suitability for a given use. These parameters should be specified in a "conceptual model". Once verified and validated, the model or simulation can be accredited for particular use.

7.2 Verification and Validation

Verification and Validation can be considered as an integrated process where the results of one task provide the basis for the next. There are also several decision points that remind the verification or validation practitioner to gather existing data or to check the task list to ensure that only necessary tasks are undertaken.

Verification starts with a list of prioritised verification requirements. Existing verification reports and data are checked to determine which requirements are satisfied or which selected verification tasks can be satisfied. Those requirements that are satisfied are documented in an appropriate report as defined by the accreditation documentation requirements.

Validation begins with a set of prioritised validation requirements, stated in terms of the functions within a model that need to be validated and the types of information needed about each. Face validation is the lowest level of validation in the set of techniques, and is generally sufficient to impart a moderate level of credibility to a model. The existing validation reports should provide sufficient information to satisfy any or all of the remaining requirements. If not, some detailed validation will be required. The least costly means of doing results validation is to use existing data. However, if not sufficient, data must be collected from test programs.

Once source data to perform results validation is available, the process for validating the model or function begins with the preparation of a validation analysis plan. The input data and any adjustable parameters within the model should be made to correspond to the values that represent the system tested and the environment in which it is tested. The model is then run, and outputs can be compared to the same parameters measured during the test. The results of the comparison will be evaluated to determine if the model accurately represents this particular real world evolution. If not, the reason for the difference, either model or source data, must be determined.

Code verification involves rigorous desk checking and software testing of the model code to determine whether the equations and algorithms specified by the design documentation are correctly implemented. It also identifies coding errors, assesses their impact on model predictions, and suggests appropriate modifications. Detailed verification gives the user confidence that the model is error free from a coding perspective, and that all the model assumptions and limitations inherent in the algorithms and equations have been identified. A fully verified model also eliminates the likelihood that poor comparison with test data in validation will be the result of unidentified coding errors.

Detailed validation consists of gathering real world data for comparison with model outputs to determine if the results are adequate for the application. Real world data are normally collected through system characterisation tests in laboratories or from system tests at test ranges. Significant savings can be realised if data are collected from

ongoing service training operations and system testing, instead of designing specific tests for model validation. Leveraging ongoing test programs is an inherent part of the recommended V&V process.

Detailed validation gives the user confidence that the accuracy of model predictions is known for specific input conditions. From this it can be determined whether or not this level of fidelity is adequate for the intended application. Again, a clear definition of fidelity requirements for the intended application is necessary before validation results can be put into context.

7.3 Accreditation

Accreditation requirements are derived from three sources; the level of credibility needed, any unique requirements specified by the accreditation authority, and requirements specified by Defence and Service policies. The level of credibility needed for a given application depends on two factors, the risk or benefit associated with the final problem outcome or decision, and whether there is any corroborating information that will be used in conjunction with the model outputs to reach a decision or influence the outcome.

Accreditation authorities tend to treat V&V in terms of model strengths and weaknesses. The first concern is what a model can do in broad terms and its prior use in any similar applications. The details of how the model functions and the manner in which it represents the real world are then considered, and finally, detailed V&V is used to build confidence that the code is error free and compares favourably with real world data at the detailed level.

The accreditation assessment begins with the comparison of the modelling requirements with the data on the model's capabilities and attributes. If no deficiencies are identified, the recommendations and rationale for accreditation are easily developed and documented. If some deficiencies are identified, an impact analysis is required for each deficiency.

The accreditation authority will consider areas of weakness within the model or simulation, how model outputs are affected by suspect model inputs, and how those outputs will most likely impact the expected application decisions or outcomes. No model is perfect; the accreditation authority's primary question will be to determine the risks if the recommended model is used. Any actions or steps that can be taken to mitigate the impact of model weakness should also be examined. Manual adjustments of input or output values or changes to functional parameters within the model may often compensate for model deficiencies and preserve the ability to use a particular model that has some deficiencies. Other work-arounds may include limiting the model's use to certain scenarios where the outputs are known to be acceptable.

The last element of the accreditation process is documenting the recommendations and rationale. The purpose of the documentation, which consists of the accreditation plan, the accreditation report, and possibly the V&V reports, is to record the final decision in a clear and understandable manner, with analytical results written so that the logic is clearly evident. The documents should contain a complete explanation of the analysis that supports the development of the modelling requirements. Also the results of the accreditation reviews must be clearly articulated along with the rationale for any judgements and the qualifications of the personnel making these judgements.

The final step in the accreditation process is obtaining the approval of the accreditation authority, namely the individual who is responsible and accountable for decisions or actions based upon the specific M&S usage. To make a sound accreditation decision, the accreditation official must understand the "big picture" along with application goals, constraints, and decision thresholds. This official should be aware of why M&S is being used, other analytic or non-M&S sources of decision support data, the scenarios and concepts that are being used in the M&S analysis, and the top level guidance concerning M&S management and usage.

7.4 Other VV&A Issues

7.4.1 Cost of VV&A

The cost of V&V should be commensurate with the importance of the M&S in decisions that ultimately affect the 'warfighter.' If it is used purely for demonstration purposes, there may be little need to conduct V&V. The costs of V&V should be borne by the user, but should be limited to those costs uniquely attributable to the use for which accreditation is sought, such as requirements review, V&V planning, assistance with or development of a good 'validation test' and the cost of developing the V&V reports.

7.4.2 Data VV&C

A model's input data is just as important as the model itself if realistic answers are to be expected. For many complex models, the model frequently IS the data. Data VV&C is, therefore, an essential part of the V&V process. In the context of VV&C, we can make the following definitions:

- **Verification:** Ensures that input data sources and collection conditions and limitations are identified, and that input data usage in the model is defined.
- **Validation:** Ensures that input data and constants are consistent with the best or accepted estimates.
- **Certification:** Provides formal approval of the validity and pedigree of a data set for use for a specific purpose.

In most cases the input data required varies according to the application. The primary objective for data certification is to ensure that the data be officially recognised as

consistent with the requirements of the application. Data VV&C gives the user confidence that the data used in the model have been obtained from credible sources, are consistently used throughout the model, and meet the requirements of the particular application.

7.5 VV&A for Networked Simulations

For networked simulations, we are not only concerned about the individual VV&A of the component models, as discussed in the previous sections, but also in the correct implementation of the DIS PDUs (when using DIS) or the correct implementation of HLA.

7.5.1 Definitions of Interoperability

There are different levels of DIS compliance, compatability, interoperability and fair fight, which have the following definitions:

DIS Compliant: A simulation/simulator is DIS compliant if it can send and receive PDUs in accordance with IEEE 1278. A specific statement must be made regarding each PDU.

DIS Compatible: Two or more simulations/simulators are DIS compatible if they are DIS compliant and their models and data send and interpret PDUs to support the realisation of a common operational environment among the systems (coherent in time and space).

DIS Interoperable: Two or more simulations/simulators are DIS interoperable for a given exercise when their performance characteristics support a fair fight to the fidelity required for the exercise.

Fair Fight: Two or more simulations/simulators can be considered to have a fair fight when differences in the simulation's performance characteristics have less effect on the results than user actions.

7.5.2 DIS Test Suite

For DIS, which is the preferred networking architecture of Navy's SEA 1412 project, a suite of DIS Test tools have been developed by the US Army's Simulation and Training Command (STRICOM) [31]. The DIS Test Suite (DTS) was developed to test DIS compliance of simulations and simulators prior to participation in DIS exercises, in an internationally accredited automated environment. The system has been used for testing simulators participating in the International/Industry Training Systems Education Conferences.

The DTS is a software package that runs on SGI or SUN workstations to enable the testing of specified PDUs. The DTS does not test the *fidelity* of the model used in the Application Under Test (AUT); rather it tests the ability of the AUT to send, receive and interpret properly formatted PDUs.

Once the DTS software is operating, the AUT is activated. The domain of the AUT is specified as the tests depend on the type of vehicle or platform being simulated. The DTS assumes that the simulator represents a vehicle or platform such as an aircraft or ship, and hence the applicability of the DTS to simulators that do not represent platforms is limited. The AUT is then moved to a specific part of a defined data base, which must be used as the geographic location for the simulation. The DTS then generates PDUs which the AUT must receive and interpret. Only PDUs exported by the DTS are used in the test. The AUT display, assumed to be an "out of the window" visual display, is then examined, visual inspection of the simulator's representation of some aspect of the exported entity's appearance or behaviour made, and a decision made on whether the specified conditions have been met. This inspection is qualitative in nature.

The DTS does not examine the numerical values of fields within the PDUs, nor does it check whether the simulation correctly passes its state values (position, velocity, orientation, etc.) in these fields. Use of the VR-Link toolkit will always generate correctly formatted PDUs given the numerical values obtained from the simulation. Testing whether these values are correct is not part of the DTS as such; they are only tested indirectly, and in a qualitative manner, from the knowledge that if they were wrong it would not be possible to view the DTS exported entities in a realistic manner.

Testing and accrediting simulators for DIS compliance is an important stage of the development of DIS within Australia. For projects such as SEA 1412, which will utilise DIS as the networking architecture, it will be necessary for an accreditation authority to be recognised to ensure full DIS compliance. AOD is currently negotiating with STRICOM to produce a DTS that can test at the DIS 2.1.4 standards.

8. Australian M&S Future Strategy

Modelling and simulation techniques are being used increasingly within Defence. A 1998 report by the Australian National Audit Office [32] stated that Defence would invest over $A1.1 billion in simulation over the following five years. Recognising the need for overall policy direction and co-ordination across the many application areas for simulation in Defence, the Defence Simulation Coordination Group (DSCG) developed a draft Simulation Policy and Master Plan [33 - 37] during the period 1996-98.

Following direction from the Defence Capability Forum, a Defence Strategic Plan [38] was then produced, based on the ideas outlined in the draft Simulation Master Plan. In July 1999, the Defence Capability Forum decided to establish the Australian Defence Simulation Office (ADSO), hence implementing one of the key recommendations of both the draft Simulation Master Plan and the Defence Strategic Plan.

8.1 Australian Defence Simulation Office (ADSO)

ADSO, headed by the Director-General Simulation (DGSIM), is a Branch within the Australian Defence Headquarters (ADHQ) Capability Staff which reports directly to the Chief Knowledge Officer. ADSO's mission is to promote the most effective and efficient exploitation of computer-based modelling and simulation capabilities for the defence of Australia and its interests, through:

a) policy direction - to advance the use of computer-based modelling and simulation (M&S) in Defence;
b) co-ordination - to enable enhanced outcomes through securing synergy and resource benefits in computer-based M&S activities across Defence; and
c) collaboration - to foster productive defence partnerships in computer-based M&S with industry, academia and overseas organisations.

Customers for ADSO outputs comprise Defence stakeholders including: Navy, Army, Air Force, Joint Commands, Strategy, Intelligence, Materiel, Capability Staff, JET/PE, and DSTO. Stakeholders external to Defence include representatives from industry, academia and overseas partners.

ADSO will provide for the needs of its stakeholders through:
- formulation of appropriate guidelines for the development, acquisition and use of computer-based modelling and simulation systems in Defence;
- securing benefits for the ADF from the co-ordination of computer-based modelling and simulation activities in Defence;
- promoting interoperability within Defence and with overseas partners to facilitate mutually beneficial collaboration;
- fostering participation by Australian industry and academia in Defence computer-based modelling and simulation activities to achieve the highest leverage for the Defence effort; and
- encouraging growth within the Defence Organisation of the skills needed in personnel who can then take full advantage of the opportunities offered by computer-based modelling and simulation for the enhancement of ADF capability.

8.2 Defence M&S – The Way Ahead

A key feature of ADSO's Policy Direction agenda [39] is to develop and implement a management structure for the formulation of Defence-wide computer-based M&S policy that satisfies Australia's defence needs. At the same time, ADSO will be working

to increase awareness and understanding across Defence of the potential, opportunities and limitations of M&S by leading, encouraging, contributing to and co-ordinating a program of focussed lecture tours, papers and demonstrations as appropriate.

ADSO will play an important role in promoting interoperability, where desired, within and among Defence Programs and with allies and partners via the adoption of international standards for the networking of distributed simulations. This was one of the cornerstones of the draft Simulation Master Plan, and has been reported widely [33- 37]. An investigation will be made into the potential for a Defence-wide M&S infrastructure that could realise benefits deriving from joint, combined and coalition interoperability.

ADSO plans to establish and lead a Defence Simulation Advisory Forum (DSAF) chaired by the Director-General Simulation (DGSIM) and drawing on representatives of its major stakeholders' base, to address Defence-wide M&S matters. Heading the list of issues for DSAF are promulgating guidelines for the development, acquisition and use of M&S systems in Defence, and specifying ways of benefiting from the co-ordination of M&S activities. DSAF will also look into achieving interoperability for collaboration both internally and with overseas partners, securing high leverage participation by industry and academia, and instituting appropriate training and career development for M&S personnel.

Opportunities for synergy across a wide spectrum of M&S applications, from stand-alone simulations to networks of interacting distributed simulations running in a common scenario, will be investigated by ADSO. ADSO proposes to define and promote standards where appropriate and possible for a common technical framework (architecture, conceptual models, data standards, networking standards) and common support services (networks, databases, supporting tools) to achieve a cost-effective level of interoperability.

ADSO plans to determine feasibility and progress development of standards and procedures for validation, verification and accreditation of computer-based models and simulations. It will also plan for the development of a Joint Synthetic Environment (JSE) concept demonstrator, through linking several simulation systems within a common technical framework and support services.

ADSO proposes to sponsor DSTO work to advance Defence's R&D activities designed to maintain knowledge about, and participation in, the development and applications of emerging M&S technologies. ADSO will therefore monitor and contribute to efforts by DSTO to maintain and strengthen links with international M&S agencies, and promote collaboration in research, development and information exchange with other countries through bilateral and multilateral arrangements.

An important early venture will be the management of a contacted feasibility study with industry for the definition of a Joint Synthetic Environment capability to meet identified Defence stakeholder needs.

In 1997 [33] it was envisaged that it would take around ten years before the M&S capabilities listed above, including the use of a Joint Synthetic Environment for a multitude of uses such as training, analysis and acquisition, would be fully utilised in a seamless manner by the Australian Defence Department. The establishment of a Joint Synthetic Environment would be the first step, and would be best utilised initially in a military training role. This would then allow the opportunity to validate the system (with a comparison able to be made with the results from live training) before it was extended for use in analysis and acquisition.

9. Simulation Interoperability Standards Organisation (SISO)

The Simulation Interoperability Standards Organisation (SISO) is an organisation dedicated to the promotion of modelling and simulation interoperability and reuse for the benefit of diverse M&S communities, including developers, procurers, and users, world-wide. SISO promotes itself as the world's foremost organisation for anyone, anywhere, interested in the interoperability and reuse of M&S resources. SISO workshops and meetings have become the favoured meeting places for M&S professionals to share experiences and knowledge. Detailed explanations of the organisation, standards development procedures, and conference activities, can be found within the "SISO Policies and Procedures" document [40].

SISO's mission is: *To provide an open forum that promotes the interoperability and reuse of models and simulations through the exchange of ideas, the examination of technologies, and the development of standards.* This mission statement reflects the multiple dimensions of SISO. A climate of openness, innovation and technical excellence is promoted. Meeting on this common ground, the membership share ideas, debate issues, reach consensus agreements, and develop standards. This can only benefit simulation interoperability and reuse.

To fulfil the precepts laid out in SISO's vision and mission statements and to build upon the operating principles embraced, SISO will focus on four areas:

- broadened participation;
- standards development;
- workshops and conferences; and
- independence.

9.1 Broadened Participation

The M&S community (especially in the USA) is fragmented by numerous barriers that breed "stovepipe" solutions diametrically opposed to interoperability and reuse of M&S resources. Many communities do not work together toward common solutions. Furthermore, those communities that have traditionally worked toward M&S interoperability have been dominated by the US DoD, whose interests are not inclusive of all M&S domains.

SISO is in the preliminary stages of breaking down traditional barriers and bringing together various communities to develop common solutions for shared problems. To fully satisfy the SISO vision, effort is being made to broaden the representation of communities not previously involved. SISO is also keen to ensure a better balance of participation from all communities so the process will not be dominated by any one facet of the M&S community.

An active outreach program is essential. SISO aims to establish its role by educating the M&S community on the value of standards that promote interoperability and reuse. SISO actively persuades members of the M&S community to become further involved. Examples of areas SISO aims to fully embrace are:

- non-DoD government activities;
- academia;
- medical profession;
- Virtual Reality Modeling Language (VRML) community;
- entertainment and gaming industry;
- commercial transportation industry;
- city planners, industrial developers, and emergency management; and
- M&S practitioners using live systems, legacy models, distributed interactive simulations (DIS), and aggregate level simulation protocols (ALSP) simulations.

This list is incomplete. For SISO to grow to its full potential and achieve significant advances in interoperability and reuse of M&S resources, participation must be open to the entire M&S community.

9.2 Standards Development Process

The development of meaningful standards is a critical SISO activity. Such standards are the greatest contributors toward broad solutions for interoperability and reuse. To be valuable, standards must be responsive to the M&S community's needs, and be timely, relevant and of excellent quality.

To ensure the most efficient standards development process possible, SISO is trying to ensure that it is responsive to the communities it serves, developing standards that

satisfy their needs. This can be accomplished both within the workshop structure, and outside the structure, with the industry, government and academic communities.

To be valuable to the user communities, these products must be delivered in a timely manner. In the fast-changing field of interactive simulation, SISO realises it must deliver its products quickly to maximize their intended benefits. This is accomplished by keeping Standards Development Groups small, tightly focussed, and well supported, and by adhering to the principles of openness and responsiveness.

SISO aims to deliver products that are top-quality and relevant to the various user communities. If SISO standards and other products do not add value for the user, then they will not be used. Conversely, if the products are of value, they will be widely used, satisfying their intended purpose of enhancing interoperability and reuse.

9.3 Workshops and Conferences

Historically rooted in the Distributed Interactive Simulation (DIS) Workshop, the scope of the Simulation Interoperability Workshop (SIW) has now expanded to encompass a broader range of simulation issues and communities, including US DoD and other government and non-government applications. Workshop participants include simulation developers, simulation users, and operations analysts, from various government, industry, and academic communities.

The SIW focuses on issues involving distributed interoperable and composable simulations, reuseable components, and on the development of a common process model for designing, composing, executing, and analyzing the results of simulations, as articulated in the US DoD High Level Architecture for Modeling and Simulation. The various Workshop Fora provide opportunities for user and technical communities to meet, share ideas and experiences, identify ways to make distributed simulation more effective and efficient, and support the development of appropriate interoperability standards.

The Workshop includes tutorials, papers on state-of-the-art experiences, identification and discussion of interoperability issues, and presentation of proposed solutions. As these solutions are prototyped and demonstrated, they become candidates for possible standards within relevant simulation communities.

Upon approval by the SISO Executive Committee, a Standards Development Group is formed, drawn primarily from the Workshop Forum/Fora proposing the standard. The Standards Development Group reports regularly to the relevant Workshop Forum/Fora regarding its progress, and seeks comments and feedback. When the proposed standard is judged ready for formal balloting, an appropriate balloting group is formed in accordance with the rules of the IEEE Computer Society Standards Activity Board.

SIW Fora provide an opportunity for members of the Modeling and Simulation community who share common interests and/or are involved in similar functions in various organizations to exchange ideas, information, and technology, to share "lessons learned," and to identify areas where common standards and practices will improve simulation interoperability and reuse. A description of each of the Workshop Fora is included at Annex A.

SISO aims to become the "crossroads" of the M&S community. SISO meetings and workshops should be the natural venue to share lessons learned, discuss innovative solutions, and plan strategies that optimise interoperability and reuse. This will enable professionals interested in interactive simulation to enhance the interoperability and reuse of M&S resources.

To reach its full potential, SISO must accomplish two things:

a) The semi-annual SIWs must continuously adapt to provide relevant fora that best meet the needs of the participants; and

b) SISO must work with other professional bodies to host joint ventures. These additional gatherings must focus on key elements of interactive simulation technology and its application to various technology areas.

9.4 Vision for SISO

To best realise the stated vision, SISO aims to stand on its own (independent from US DoD funding). It aims to be self-contained and able to conduct its business independently. This will allow SISO to work to the best interests of the broad M&S community. The M&S community is perceived by SISO to be fragmented by numerous barriers that breed "stovepipe" solutions diametrically opposed to interoperability and re-use of M&S resources. Many communities do not work together toward common solutions at all. In addition, there are commercial pressures that continue to drive fragmentation. SISO aims to break down traditional barriers and bring together various communities to develop common solutions for shared problems. For SISO to grow to its full potential and achieve significant advances in interoperability and re-use of M&S resources, participation is open to the entire worldwide M&S community.

10. International Simulation Advisory Group

10.1 Formation of ISAG

Whilst the UK's influence increased at the SISO Workshops, the UK Government and industry had no input to the standardisation process. This was a major concern, with the UK Government (in 1995) about to commit £200-300m for at least one training

simulation, the Combined Arms Tactical Trainer (CATT). The UK Ministry of Defence (through the UK Simulation Interoperability Working Group) approached the DIS Steering Committee (as it was then known), to seek a place at the table for the UK. The SISO Chairman (from HQ STRICOM at the time), suggested that instead of just the UK, other European nations should also be represented. He asked the UK SIW to organise this.

As a result, an embryonic organisation (European Simulation Interoperability Working Group (ESIWG)) was established. The group consisted of 11 European Nations with 4 Co-chairmen, UK, France, Germany and The Netherlands. This activity was unfunded and the Co-chairmanship format was agreed in order that one or more Co-Chairmen could attend most of the meetings. It also avoided international sensitivities over leadership. The ESIWG was given a place for the last two years of the old DIS Steering Committee, who were very keen to hear about major Non-North American DIS issues.

In 1996 SISO broke away from DOD/DMSO and set up as an independent standards body, similar to the US IEEE. Organising committee membership was dominated by US Internet voting procedures.

By the time SISO was launched, ESIWG had grown to have Points of Contact (POCs) in 36 Nations and 4 organisations (Eurocontrol, European Space Agency, NATO and Simulation Computer Society (International)). As it was no longer solely a European organisation, it was renamed in 1997, the International Simulation Advisory Group (ISAG).

The Swedish Government has funded a web site [41] and is financing administrative support. The Co-chairmen have been expanded to 6, with Australia and Sweden being added. ISAG conducts its main annual meeting in conjunction with the International Training and Education Conference (ITEC), usually held in The Hague, The Netherlands in April.

SISO approved a formal associate recognition once ISAG had approved a Charter. This occurred at the 3rd ISAG meeting at ITEC98. SISO has now formally recognised ISAG as an SISO affiliated organisation. The USA has joined ISAG and DMSO provides the POC. Recently the UK Co-Chairman of ISAG was elected to a place on the SISO Executive Committee.

10.2 ISAG Aims and Achievements

ISAG aims to raise those issues causing international concern with the most appropriate SISO committees. It does not replace or interfere with the normal flow of Workshop papers or the activities of the SISO Committee members, but is responsible for action on issues such as the release of the RTI software to all practitioners via the Internet, as requested during 1997. ISAG backing helped the DMSO Director to win his case for release.

In 1999, ISAG requested the formation of a SISO Forum be at which DIS IEEE-1278 transition issues could be discussed, to simplify the transition to HLA. This issue was raised at the DMSO Industry Steering Group Industry Briefing Days in Washington, and with considerable support from the US community, the Forum is now in place.

In the future, ISAG can be useful to SISO when SISO moves towards incorporating the US IEEE standards as ISO standards. To do this, SISO will need to ensure that all interested Nations make the same request, in the same committee, in each National Standards Organisation. ISAG is ideally suited to co-ordinate that process. There are signs that for commercial reasons, the US may try to retain the simulation standards as US IEEE only. At first sight this could be commercially damaging to the industries of other Nations who could find that they have no choice but to buy, and recommend to clients, only US products such as the RTI. The ISO route is being followed for the SEDRIS standards and the sponsors are keen to involve ISAG when the time comes for co-ordination.

The ISAG Charter and list of Nations and Organisations associated with ISAG is included at Appendix B.

11. Discussion

Advanced Distributed Simulation technologies are gradually being introduced into Australia. Terms and acronyms used within ADS are in a glossary at Annex C. Initially linkages for fielded military applications (networked simulators) should be developed using DIS, since HLA is still a relatively immature technology. An upgrade path for DIS compatible simulators to HLA has been identified, and will provide sufficient compliance with HLA for interoperability with Australia's main allies. HLA for DSTO research projects (such as Virtual Ship) is supported, but a DIS to HLA transition path is favoured for in-service simulators, to allow flexibility.

Like most Defence Forces worldwide, the ADF is examining the issue of which approach to adopt:
- the DIS Protocol for its networked simulation infrastructure;
- HLA, which is still evolving; or
- DIS initially, whilst developing a coherent migration strategy towards HLA for the future.

The Air Operations Division of DSTO has experience in the area of DIS and HLA over a number of years [42]. Based on both this background, and extensive discussions with both overseas and local simulation personnel, the authors consider it to be premature to recommend mandating HLA for the ADO, for the reasons outlined in the following sections.

11.1 IEEE Standardisation

The format and content of the data contained within DIS PDUs has been standardised by the US IEEE. Therefore any DIS compliant simulators will be able to interoperate using one of the following three IEEE standards:

a) IEEE 1278-1993
b) IEEE 1278.1-1995
c) IEEE 1278.1a-1998

In contrast, HLA is not standardised at this level since its data format and content are not pre-defined. The standardisation of the HLA methodology is underway [12] - with three draft standards (designated by the **P**) currently having been formulated:
a) P1516 – Framework and rules
b) P1516.1 – Federate interface specification
c) P1516.2 – Object Model Template

Although parts of HLA are going through the IEEE standardisation process, this is not complete and it would seem premature to consider mandating a technology that is not yet an international standard.

Once the HLA methodology has achieved IEEE standardisation, it will be necessary to standardise the reference FOMs (such as the RPR-FOM), in order to obtain a similar level of standardisation (and interoperability) currently achieved by DIS.

11.2 Cost and Risk

To enable interoperability, existing ADF Projects such as SEA 1412 and Virtual Air Environment are initially using DIS. Adding an Advanced Distributed Simulation interface (be it DIS or HLA) to an in-service training simulator, may cost of the order of several million dollars. At a DMSO-run HLA course held at Salisbury in late 1999, it was mentioned that a small US Navy wargame was converted to HLA at a cost of roughly $US1M.

Mandating HLA would raise the issue of what FOM is to be developed and who uses it. Until such an Australian Defence FOM (also compatible with Allies) is agreed upon, HLA cannot viably replace DIS for training simulators. Changes or modifications to a FOM will also be expensive to implement. In addition, tools such as viewers and loggers will also need to be individually created.

11.3 Interoperability with Allies

The major US Programs are still using DIS. For example, the USN's $US750M Battle Force Tactical Training (BFTT) project currently uses DIS and will migrate to HLA over several years. To maintain interoperability, the RAN cannot (at present) contemplate

migration to HLA (SEA 1412 Project) until the USN BFTT project has defined their FOM and migration process. The UK Combined Arms Tactical Trainer (CATT), at a project cost of £300M, will also use DIS (with a transition to HLA over many years). The US Army's Close Combat Tactical Trainer (CCTT) will evolve from DIS to HLA in a similar fashion.

A workshop was held recently in Australia [43] in which the problems experienced in the US services with the HLA mandate were discussed in a panel forum.

11.4 Interoperability within Australia

To achieve HLA compliance, all systems must decide on the same FOM for interoperability. This invites the question as to which FOM does the ADO use? – one or several different ones. Should the ADO develop its own FOM, or use ones developed overseas? In order for networked simulators to be HLA compliant, all systems must use the same FOM for interoperability. A multiplicity of FOMs will create stove-piped simulation systems, the antithesis of the goal of interoperability in a Joint Synthetic Environment.

AOD staff participated in the balloting process for the RPR-FOM [9], which provides a transition path to HLA by mapping DIS Protocol Data Units. This is the *only* FOM being promoted by the Simulation Interoperability Standards Organisation (SISO).

In contrast to HLA, DIS provides *out of the box* interoperability – all DIS compliant systems can talk to each other. Thus if SEA 1412 and VAE use DIS they will automatically be able to interoperate – if they used HLA with different, incompatible, FOMs this would be impossible. SEA 1412 and VAE Projects need to be able to interoperate with each other and also other systems coming on line.

11.5 Lack of COTS Support

DIS has many Commercial Off The Shelf tools since the *data* are standardised. By definition, HLA data being exchanged is only standard for a specific federation. This means that standard tools such as viewers and loggers will need to be developed separately for each FOM.

11.6 Recommendations

For military simulators (especially those to be used primarily for training), DIS is recommended as the current networking standard. Such simulators require the flexibility to interoperate with other simulators, but it may not be known in advance (at the time of development and deployment) with which other simulators they might interoperate. The advantage of DIS is that all DIS-enabled simulators can interoperate. With HLA, the exact data transfer mechanism, the FOM, must all be agreed in advance. It is necessary to know with which simulators you wish to network. If HLA is deemed

to be absolutely necessary as the networking architecture, then the RPR-FOM should be specified.

For research projects and simulations used for analysis, which can be designed to network with other simulations known in advance, the new HLA may be preferred. The Virtual Ship Project is an excellent example of a DSTO research project, where the use of HLA is ideal. Since the interoperability can be planned ahead, the FOM can be tailor-made to suit the application.

HLA is new and exciting technology that will ultimately offer many advantages over DIS. It is an excellent research area for DSTO, with its long tradition of M&S, to investigate in the laboratory environment. An Australian Defence Organisation FOM does not exist and should **not** be developed until agreement is reached on likely allied Nation projects with which Australia wishes to interoperate (eg BFTT). Therefore, it is highly **premature** to mandate its use for the ADO. Mandating HLA would compromise interoperability between ADF in-service (or soon to be in-service) training systems and with the US and other allies.

The authors recommend a cautious approach to the introduction of HLA into the ADO following the US experience. One of the roles of ADSO will be to ensure that, through appropriate Defence Exchange Agreements, the ADO can work with our allies (particularly the US and UK) to ensure that ADF in-service training systems will migrate to HLA while retaining interoperability.

12. Conclusions

The US DMSO has initiated a comprehensive range of programs to simplify the development of M&S within their military. This was started to address existing deep-rooted problems within their community for development of M&S. Various programs were commenced to address interoperability, data standardisation, terrain database interchange, common conceptual models of military operations, *inter alia*. Australia can benefit through attendance at workshops and conferences where these new programs and standards are being developed.

A key issue is the gradual introduction of Advanced Distributed Simulation technologies into Australia. Both the ADF and DSTO have various active programs using these technologies. Initially linkages will be developed using DIS, since HLA is still a relatively immature technology. An upgrade path for DIS compatible simulators to HLA has been identified This will provide sufficient compliance with HLA for interoperability with Australia's main allies.

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14. Glossary of Acronyms

ADAC2s	Air Defence and Airspace Command, Control and Communication system
ADF	Australian Defence Force
ADGE	Air Defence Ground Environment
ADO	Australian Defence Organisation
ADS	Advanced Distributed Simulation
ADSO	Australian Defence Simulation Office
AEW&C	Airborne Early Warning & Control
AOD	Air Operations Division
AOSC	Air Operations Simulation Centre
API	Application Programmer's Interface
ARH	Armed Reconnaissance Helicopter
AUT	Application Under Test
BFTT	Battle Force Tactical Trainer
C^3I	Command, Control, Communications, and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Search & Reconaissance
CATT	Combined Arms Tactical Trainer
CCTT	Close Combat Tactical Trainer
CGE	Computer Generated Entity
CGF	Computer Generated Forces
CMMS	Conceptual Models of the Mission Space
COTS	Commercial-Off-The-Shelf
DDG	Guided Missile Destroyer
DIS	Distributed Interactive Simulation
DIU	DIS Interface Unit
DMSO	Defense Modeling and Simulation Office (US)
DoD	US Department of Defense
DSAC	Defence Simulation Advisory Council
DSTO	Defence Science & Technology Organisation
DTS	DIS Test Suite
EDCS	Environmental Data Coding Specification
EMPDU	Emission PDU
ESIWG	European Simulation Interoperability Working Group
ESPDU	Entity State PDU
EXC3ITE)	Experimental C3I Technology Environment
FFG	Guided Missile Frigate
FOM	Federation Object Model

HiL	Human-in-the-Loop
HLA	High Level Architecture
HQADF	Headquarters, Australian Defence Force
IEEE	Institute of Electrical and Electronic Engineers
IO	Information Organisation
ISAG	International Simulation Advisory Group
ISDN	Integrated Services Digital Network
ISO	International Standards Organisation
IST	Institute of Simulation and Training (US)
ITEC	International Training and Education Conference
JASA	Joint Accreditation Support Activity (US DoD)
JORN	Jindalee Operational Radar Network
JSE	Joint Synthetic Environment
LAN	Local Area Network
M&S	Modelling and Simulation
MEL	Master Environment Library
ModSAF	Modular Semi Automated Forces
MORS	Military Operations Research Society
MWTC	Maritime Warfare Training Centre
OBTS	On Board Training Systems
OMT	Object Model Template
PDU	Protocol Data Unit
RAAF	Royal Australian Air Force
RAN	Royal Australian Navy
RPR-FOM	Real time Platform Reference FOM
RTI	Run Time Infrastructure
RTM	Requirements Traceability Matrix
SBA	Simulation Based Acquisition
SEDRIS	Synthetic Environment Data Representation and Interchange Specification
SISO	Simulation Interoperability Standards Organisation
SIW	Simulation Interoperability Workshop
SOM	Simulation Object Model
SRM	Spatial Reference Model
STF	SEDRIS Transmittal Format
STRICOM	Simulation Training and Instrumentation COMmand (US Army)
TTCP	The Technical Co-operation Program
UML	Unified Modeling Language
USN	United States Navy

VAE	Virtual Air Environment
VRML	Virtual Reality Modeling Language
VSAWG	Virtual Ship Architecture Working Group
VSEM	Virtual Ship Execution Manager
VV&A	Verification, Validation and Accreditation
VV&C	Verification, Validation and Certification
WAN	Wide Area Network

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Appendix A: SISO WORKSHOP FORA

The following sections describe the SISO workshops.

A.1. Analysis Forum (ANL)

ANL is concerned with interoperability issues and uses of distributed models and simulations for analysis. ANL encourages the education of the analysis community about Advanced Distributed Simulation (ADS) and of the developers of ADS about analytic requirements. ANL currently focusses on process developments that will identify user requirements. Topics of interest include:

- experiences doing pre-exercise, run-time, or post-exercise analysis in ADS;
- the role of the analyst in the HLA FEDEP;
- processes to develop requirements for analytic federates and federations;
- identification of model and simulation interoperability issues for analysis;
- methods to address experimental design that incorporate ADS as an analytic tool; and
- issues for analysis in Simulation Based Acquisition.

A.2. Research, Development, and Engineering Forum (RDE)

RDE is concerned with issues and uses of distributed models and simulations within the Research, Development and Engineering domain. RDE currently focusses on interoperability of distributed simulation in supporting user requirements. Topics of interest include:

- experiences in creating, implementing, operating or delivering simulations for RDE problems;
- processes to develop interoperability or model re-use requirements for RDE federates and federations; and
- processes, procedures or methods of evaluating fidelity requirements and model credibility for experimentation.

A.3. Test and Evaluation Forum (TE)

TE is concerned with uses of advanced distributed simulation (ADS) in test and evaluation (T&E), including the incorporation of live entities with virtual and constructive simulations, and the linking of historically stand-alone T&E facilities into distributed simulations. Currently, topics of interest are:

- experiences using ADS to support T&E;
- experiences linking ADS and test ranges; and
- interoperability testing.

A.4. Training Forum (TRAINING)

TRAINING is a newly created forum, through the merger of the former Small Team Training (STT) and Staff Level Training (SLT) fora, that promotes discussion of issues involving simulation in training. TRAINING is concerned with the planning, management, requirements, and use of simulations that provide individual, sub-team, and team training to system operators, team leaders, and tactical, operational, and strategic decision makers. There is a special interest in the User perspective (training organizations, sponsoring agencies, and those being trained) in all simulation environments. In particular, TRAINING is currently addressing the following areas:

- results and/or lessons learned from the conduct of major or significant training events;
- simulation training effectiveness in a multi-echelon environment;
- interoperability between simulations and C4I systems directly in support of staff level training environments;
- validity and interoperability of simulation and operational databases used for distributed training;
- common requirements across diverse simulation programs including needs for common FOMs/SOMs;
- distributed mission training, non-combatant (Military Operations Other than War (MOOTW)), training exercises, and training the Digitized Force; and
- methodologies for mapping of fidelity measures to training requirements.

A.5. Specialty Area Tracks

Specialty Area Fora bring together specialists from different communities to discuss interoperability and component re-use issues. Because the interests of participants may span multiple areas, the Specialty Area Fora are organized into Tracks to facilitate planning and scheduling.

A.5.1 Run-Time Infrastructure and Communications Forum (RTI&C)

RTI&C deals with the technical aspects of getting simulations to interoperate. Current topics of interest to this forum include:

- RTI implementation descriptions;
- RTI performance characteristics;
- new and developing communications methods and standards, and how they can be applied;
- to distributed simulations (eg., reliable multi-cast, active networks);
- alternate federation compositions, such as composable federations;
- single process federations; single address space federations, etc; and
- implementations of Quality of Service capabilities in an RTI.

A.5.2 Live Interaction Forum (LIVE) (co-administered by C4ISR)

The Live Interaction Forum provides an opportunity for those interested in live simulations to exchange information and share experiences. The Forum is focused on the issues associated with simulations that depend upon live participants and the associated simulation instrumentation. Included areas of interest are architecture, protocol, instrumentation, simulation management, and numerous technical issues that effect stand-alone live simulations, as well as the integration of live simulations with virtual and constructive simulations for training, test and evaluation, and other applications.

A primary purpose of the forum is to evaluate evolving standards and supporting documents to ensure that they realistically promote interoperability with live simulations and accurately represent the boundaries of normal operational parameters.

Of particular interest to the Forum are issues concerning: known or anticipated shortcomings in existing or planned architectures and implementations for interoperable simulations, technical issues associated with the live simulation domain applications and lessons learned in live simulations for training or T&E.

A.5.3 Synthetic Natural Environment Forum (SNE)

SNE addresses issues concerning digital representations of the natural environment, including air, space, land, and water. Relevant topics span the life cycle of digital environmental representations, including requirements definition, data collection and production, integration and validation, extension, transmission, tailoring, sharing, and maintenance.

A.5.4 Sensor Forum (SENS)

The Sensor Forum (SENS) is an interdisciplinary SISO forum chartered to address the integration of sensors and sensor models into live, virtual and constructive simulations. SENS goal is to recommend practices and standards in the areas of representation, interoperability, fidelity, correlation and interchange mechanisms for use by the simulation community. The SENS forum focusses on end-to-end systems, including propagation effects and modelling of sensor and emitter systems. Functional systems of interest incorporate mechanisms such as navigation, communication, search, detection and tracking. The sensing regimes used in these systems include, but are not limited to, acoustic, electromagnetic (radar, RF etc.), electro-optical (IR, visible, etc.), chemical, nuclear and biological characteristics.

A.5.5 Federation Development Process Forum (PROC)

PROC is focussed on the process of federation development and execution through sharing of practical federation development experiences across the HLA user

community, facilitating the identification of new and different approaches to federation development activities, and supporting the long-term evolution of a generalized process model for HLA federations (HLA FEDEP). Current topics of interest are:
- Federation objectives development;
- Federation scenario / conceptual model development;
- Federation design approaches / techniques; and
- Object model development.

A.5.6 Exercise Management Forum (EMF)

The Exercise Management Forum provides an outlet for discussing tools that automate the evolving Federation Development Process. The Exercise Management Forum Proposes functionality and interface standards for tools in areas, such as:
- Planning;
- Initialization;
- Monitoring;
- Runtime Controls;
- Data Collection;
- Data Analysis;
- Visualization; and
- After Action Review.

A.5.7 Verification, Validation & Accreditation Forum (VVA)

VVA is focussed on methodologies, procedures, and associated techniques that may be used to establish credibility of federations. The forum objectives emphasise quality (eg. building in authoritative representations and behaviors) and risk management. VVA will support the development and evolution of VV&A guidance to supplement the federation development/application lifecycle process model documentation. Present topics of interest include:
- empirical data on the Fidelity Conceptual Framework (see FEX-ISG page on the SISO web site);
- validation of human behavior representations;
- substantive interoperability; and
- lessons learned on VV&A of distributed simulations, with emphasis on conceptual models (particularly comparisons of actual conceptual model development experiences to the conceptual model framework).

A.5.8 Testing Forum (TEST)

TEST will discuss techniques, tools, drivers, and methodologies for testing as it applies to HLA, SISO Standards, and the transition of legacy simulations to SISO standards. Issues raised in this forum will provide guidance for the development of testable standards.

Testing areas include, but are not limited to:
- Compliance Testing;
- Interoperability Testing;
- System Testing;
- Integration Testing;
- Regression Testing;
- Performance Testing;
- Acceptance Testing;
- Stress Testing; and
- Scenario/Exercise Testing.

A.5.9 Command, Control, Communications, Computers, and Intelligence Forum (C4I)

C4I is concerned with the modeling and simulation of C4I systems in constructive, virtual, and live environments. C4I is particularly interested in the results and "lessons learned" of specific projects/experiments, as well as overarching conceptual issues involving the interoperability of simulation systems in the following areas:
- C4I functionality, both individual systems and overall processes and cycles;
- interoperability of real systems and simulation systems, and associated issues such as:
  - common (shared) data/object models and reference architectures;
  - Measures of Effectiveness (MOEs) for C4I systems, and instrumentation of real and simulated C4I systems to extract information for MOEs and validation;
  - implications of HLA, DoD JTA, DII COE, and other respective standards;
  - embedding of simulation systems with real-world C4I systems; and
  - the coupling of real and simulated C4I systems with real and simulated sensor and weapon systems, and sensor fusion issues.

A.5.10 Information Operations -Intelligence, Surveillance and Reconnaissance Forum (IO-ISR)

IO-ISR is concerned with the interoperability of simulations that represent systems and activities in the following areas:
- Information Operations (IO), with particular emphasis on research into:
  related human behavioural and command decision process modelling;
  supporting taxonomies, lexicons, metrics, and metric collection processes;
  data sources supporting establishment of causal relationships between IO techniques and observed effects; and
  the modeling of such relationships,
- Intelligence collection, processing and dissemination, with particular emphasis on research into:
  the relationship of the output of the overall intelligence cycle to its impact upon the warfighter (ie., "sensor-to-shooter" analyses), as well as issues within the intelligence cycle itself;

the representation of "attributes" which can be sensed by ISR sensors, emanating from targets, decoys, and the environment (eg. optical signatures, thermal signatures, SAR returns, MTI returns, etc.); and the structure, contents and availability of databases relevant to the authoritative description of US ISR capabilities and overall opposing force systems, processes and behaviours.

A.5.11 Federation Implementers Forum (IMPL)

IMPL addresses hands-on experience in developing Federations, particularly lessons learned from using the latest HLA-related developments. Present areas of research are:
- legacy simulation migration to HLA;
- SOM/FOM interoperability;
- Federate/Federation performance, especially WRT large, real-world simulations;
- Federate/Federation development tools;
- exercise execution (eg., performance issues resulting from the RTI); and
- experiences using the RTI, especially time management, data distribution, ownership, and management.

A.5.12 Vehicle/Weapon System Modeling Forum (VWS)

The primary focus of VWS is the development and re-use of weapon/vehicle system simulations, including all classes of manned and unmanned weapon and vehicle systems that operate in space, air, ground, and sea environments. VWS addresses the representation of vehicle/weapon systems in constructive, virtual, and live simulations at engineering, engagement, mission, and campaign levels of aggregation.

Present areas of research are:
- development and descriptions of weapon system or vehicle simulations;
- conversion of weapon system or vehicle simulations from DIS to HLA compliance;
- weapon system and vehicle Simulation Object Models (SOMs), model and data repositories, and class taxonomies;
- methods to capture the "conceptual models" of weapon systems or vehicles for use in simulation;
- standards needed to enhance the representation of weapon systems or vehicles within simulation federations;
- integration of weapon/vehicle systems simulations/simulators in acquisition processes;
- development of Distributed Product Descriptions (DPDs), Smart Product Models (SPMs), or Digital System Models (DSMs) that portray weapon/vehicle systems in an SBA environment;
- development of embedded simulations for weapon/vehicle systems; and
- simulations/simulators for advanced weapons, such as Directed Energy Weapons (DEW).

A.5.13 Behavior Representation Forum (BEH)

BEH examines the realistic representation of human and organizational behavior within models and simulations. Present areas of research are:
- the representation of behavior within IO-ISR, SNE, PROC, TRAINING;
- validation of human behaviour models, particularly lessons learned; and
- extension/amplification to the concepts related to a standardized format for the transmission of the knowledge base component of a reasoning system.

A.5.14 Logistics Forum (LOG)

LOG focusses on issues related to logistics simulation, including supply chain logistics, logistics business practices, and the representation of logistics systems at the national, strategic, operational, and tactical military levels. Appropriate aspects of coalition partner, host nation, and/or non-military/commercial logistics are also of interest.

Current areas of specific interest are:
- lessons learned making a logistics simulation HLA-compliant (including issues of object ownership transfer and aggregation/deaggregation of data used by systems of different levels of fidelity);
- integration of logistics simulations with combat simulations, OOTW tools, C4ISR systems, emergency planning systems, or other logistics systems;
- Simulation Based Acquisition (SBA) and its relationship to logistics, such as the effect of acquisition on logistics infrastructure, supply chain, and reliability; and
- treatment of logistics in future distributed simulation systems, such as JSIMS, JWARS, and JMASS.

A.5.15 Federation Performance Forum (Fed_Perf)

This Forum focuses on the efficiency and effectiveness of Federation performance. Present topics of interest are:
- metrics for characterizing the performance of individual Federates, composite Federations, and Run-Time Infrastructures in various applications;
- scalability of Federation performance with Federation size and complexity;
- experiences and "lessons learned" from those who have built and optimized sizeable Federations for practical applications; and
- tools and techniques for predicting and optimizing the performance of a large, complex Federation.

A.5.16 Non-HLA Environments Forum (Non-HLA)

SIW recognizes that many distributed simulations have different types of interoperability protocols, including the Distributed Interactive Simulation (DIS) protocols of IEEE Standard 1278, Common Object Request Brokering Architecture (CORBA), Web-based simulations, entertainment oriented protocols, and future

interoperability protocols. SIW conferences provide an opportunity for those involved with Non-HLA interoperability protocols to share their insights and issues with one another. In addition, this forum has a focus session on products and services to help migrate users of DIS to HLA. The SIW splits this forum into two distinct areas:

- DIS related topics: products/services, lessons learned, new programs using DIS, and new research using DIS; and
- CORBA, Web-based simulations, future protocols, etc.

A.5.17 Real-time Platform-level Reference Federation Object Model Forum

The RPR Virtual Forum deals with uses of and extensions to the Real-time Platform-level Reference Federation Object Model (RPR FOM). RPR FOM version 2.0 is presently under development.

Current topics of interest to this forum include:

- RPR FOM federation implementations, legacy transitions and new developments - overview, examples, lessons learned, etc.;
- RPR FOM extensions, implementation, use, and the requirements that necessitated the additions; and
- proposals for RPR FOM version 3.0 - additions and modifications that fully exploit HLA functionality, even in areas not supported by DIS.

A.5.18 Simulation Based Acquisition Forum (SBA)

This forum focuses on issues and approaches for achieving consistent representation and interoperability among multiple, distributed models and simulations used in collaborative environments supporting commercial product developments and system acquisition. The goal is to develop a framework for identifying candidate SISO products needed to support this application domain.

Topics of special interest include:

- operational and simulation system architectures that provide a frame of reference for defining interfaces, interactions and economic benefits in this application domain;
- use of models and simulations to form a common context and shared environment enabling collaboration and integration among end users, developers, suppliers, supporting systems, service providers and decision makers; and
- specifications for standardizing model and data descriptions, interchange formats and repositories.

A.5.19 Simulation Interoperability through Components Forum (SITC)

The SITC virtual forum addresses the use of component technology to support simulation interoperability. In particular, the following topics are of interest:

- component frameworks for supporting simulation interoperability, including extensions to current frameworks and simulation interoperability standards to support component technology;
- components for simulation design, including Base Object Models (BOMs);
- metadata for components to support the characterization of components and their composition as part of a simulation system;
- components for simulation implementations; and
- management issues associated with simulation component use, including: simulation component repositories, VV&A and testing issues, and tool support.

Appendix B: ISAG Charter and List of Nations

B.1. AIM OF THE ISAG

1. The aim of the ISAG is:

"To provide a co-ordinating focus for major international interests in the work on modelling and simulation standards being carried out by the Simulation Interoperability Standards Organisation (SISO)."

B.2. FURTHER OBJECTIVES OF THE ISAG

2. In addition the ISAG has the following specific objectives:

a) ensure that the leadership of SISO understands the specific issues and concerns of the international community in support of SISO's goal of development of standards which can be adopted by the international community;

b) ensure that SISO understands the international aspects of simulation interoperability and that members of SISO from areas/nations/organisations other than the US understand and support SISO standards so that they can promote their adoption as local standards in their own Area/Nation/Organisation as well as ISO.

B.3. APPOINTMENT OF NATIONAL POINTS OF CONTACT (POCs)

3. Each Area/Nation/Organisation is responsible for appointing one person as a Point of Contact by whatever means that Area/Nation/Organisation considers is the correct mechanism. It is recommended that within his Area/Nation/Organisation the POC has connections to Government, Industry and Academia.

B.4. APPOINTMENT OF CO-CHAIRMEN

4. There will be six Co-chairmen, and they will initially (from April 1997) be the six National POCs from Australia, France, Germany, Sweden, The Netherlands and the United Kingdom. At each ITEC Annual Meeting, there will be a vote taken during the ISAG meeting to appoint the six Co-chairmen for the following year. After that the places for two Co-chairmen will be open for voting each year.

B.5. MEMBERSHIP

5. The membership of the ISAG is open to any person or company belonging to an Area/Nation/Organisation who has asked to be associated with ISAG and who provides a POC.

B.6. NATIONS AND ORGANISATIONS ASSOCIATED WITH ISAG

1. **UK**	**Co-chairman**	**Mr Mick Ryan**
2. **Germany**	**Co- chairman**	**Mr Ernst-Wichard Budde**
3. **France**	**Co- chairman**	**Mr Francois Heran**
4. **The Netherlands**	**Co- chairman**	**Dr Hans Jense**
5. **Sweden**	**Co- chairman**	**Mr Anders Mattson**
6. **Australia**	**Co- chairman**	**Dr Peter Clark**

7. Austria
8. Belgium
9. Brazil
10. Canada
11. China
12. Chinese Taipei
13. Croatia
14. Czech Republic
15. Denmark
16. Estonia
17. Finland
18. Greece
19. Hungary
20. India
21. Israel
22. Italy
23. Japan
24. Latvia
25. Malaysia
26. Norway
27. Poland
28. Portugal
29. Romania
30. Russia
31. Singapore
32. Slovenia
33. South Africa
34. Turkey
35. Ukraine
36. USA
37. European Space Agency (ESA)
38. Society for Computer Simulation International (SCS (I))
39. Eurocontrol
40. NATO

Appendix C: GLOSSARY OF TERMS AND ACRONYMS

NOTE: Source(s) quoted after each entry.

Accreditation. An official certification that a model or simulation is acceptable for use for a specific purpose. A formal authority is charged with approving a simulation or simulator, or network of simulations/simulators, for use for a specific purpose, eg. training. [C2]

Accuracy. The degree of exactness of a model or simulation, relative to an established standard, high accuracy implying low error. [C31]

Advanced Distributed Simulation (ADS). A synthetic environment within which humans may interact through simulations at multiple sites networked using compliant architecture, modelling, protocols, standards and databases. [C29]

Agent. Software that has the properties of autonomy (capable of independent functioning); persistence (continue functioning over time); and proactive and reactive behaviour (capable of goal directed behaviour as well as reactions to an environment). Intelligent agents also incorporate reasoning, learning and intelligence. [C36]

Aggregate. An activity that coalesces individual entities into a singular entity. [C31]

Aggregate Level Simulation Protocol (ALSP). A networking architecture allowing the interoperability of constructive simulations (wargames).

Aliasing. The name given to a wide range of undesirable visual effects caused by the quantisation of the image into pixels. Jagged and/or crawling edges, gaps in thin polygons and a tendency for small polygons to blink on and off are typical examples. [C31]

Analytical Domain. The majority of simulation models are employed in imitating the behaviour of physical systems (such as aircraft or missiles) which do not require or involve interactive human input. Simulations which require the aggregation of many systems involving human behaviour (such as air combat) may employ mathematical representations of human operators as well as of the physical systems. These models are employed in the systematic study of the behaviour and capabilities of complex systems. [C35]

Analytical Model. A model consisting of a set of solvable equations; for example, one that represents the laws of supply and demand in the world market. [C31]

Anti-Aliasing. Any software and/or hardware implementations to limit aliasing. Normally involves super-sampling the image and averaging the results into the appropriate number of pixels. [C31]

Architecture. A collection of interface standards, a common design language, and a conceptual framework for orienting discourse about modelling and simulation issues. [C2],[C14]

ATM. *Asynchronous Transfer Mode.* A networking standard for transmitting at high speeds over fiberoptic cable. [C6]

Bandwidth. A measurement of the amount of information that can be carried over a network at any given time. [C39]

BattleModel. A simulation architecture for physical entities and reasoning models represented by tactical decision making. The reasoning model within the BattleModel is dMARS (distributed Multi-Agent Reasoning System), which operates under a BDI (beliefs, desires, intentions) paradigm. [C37]

Broadcast. An addressing mode in which a Protocol Data Unit (PDU) is sent to all Distributed Interactive Simulation (DIS) nodes on a network. [C29]

Built-In Simulator. A simulator that is built-in to the system being modelled; for example, an operator training simulator built into the control panel of a power plant such that the system can operate in simulator mode or in normal operating mode. Synonymous with embedded training. [C31]

Certification: Provides formal approval of the validity and pedigree of a data set for use for a specific purpose [C2].

Client. The program in a distributed computing system that does the requesting. Clients direct the requests to servers across a network. They wait for a response from the server indicating that the request is complete. [C6]

Client/Server Model. The model of interaction in a distributed system in which a program at one site sends a request to a program at another site and then awaits a response. The requesting program is called the client; the answering program, the server. [C6]

Collision Detection. A process available in some image generators which will determine if a collection of test points (normally representing the ownership) have collided with objects in the visual database. [C31]

Combat Modelling. Any structured activity that is undertaken to represent higher level strategic guidance, doctrine operational concepts, concepts of operation and combat scenarios in terms of varying degrees of abstraction and reality. [C30]

Compatible. Two or more simulations/simulators are DIS compatible if they are DIS compliant, and their models and data that send and interpret PDUs support the realisation of a common operational environment among the systems (coherent in time and space). [C31]

Compliant. A simulation/simulator is DIS compliant if it can send and receive PDUs in accordance with IEEE Standard 1278 and 1278 (Working Drafts). [C31]

Computer Aided Learning (CAL). A method of instruction which uses computer technology to replace traditional text and classroom-based teaching. [C28]

Computer Generated Forces (CGF). A collection of unmanned battlefield entities under control as a unit. CGF replace or supplement friendly, enemy or neutral manned simulators during a specific session. If a platform level simulation entity is directly controlled by a man in the loop it is a Semi-Automated Force (SAFOR), if it is directly controlled by a computer it is an Automated Force (AFOR). [C2]

Computer Generated Imagery (CGI). The actual imagery which is created by the computer image generation process. [C31]

Configuration Management. The application of technical and administrative direction and surveillance to identify and document the functional and physical characteristics of a model or simulation, control changes, and record and report change processing and implementation status. [C2]

Constructive Model or Simulation. Models and simulations that involve real people making inputs into a simulation that carries out those inputs by simulated people operating simulated systems. Wargames, models and analytical simulations that typically involve aggregated software representations of units, their behaviour and associated outcomes. [C2], [C35]

Control Station. Facility which provides the individual responsible for controlling the simulation and which provides the capability to implement simulation control as Protocol Data Units (PDUs) on the Distributed Interactive Simulation network. [C31]

CSTT. Combat System Team Trainer. The acronym denotes the ANZAC ship operations room simulator currently under development for use at HMAS Watson. [C33]

DARPA. Defense Advanced Research Projects Agency. Formerly called ARPA, this is an agency of the US Department of Defense (DOD). It was the original funding source for, and overseer of, TCP/IP. [C6]

Data. Representation of facts, concepts, or instructions in a formalised manner suitable for communication, interpretation or processing by humans or automatic means. [C31]

Database. A collection of data, organised according to a schema to serve one or more applications. The term is generally applied to the geometrical information which the image generator will process to produce an image. As a minimum, this will include polygons which are defined by the position of their corners (vertices) and some method of specifying colour. In more advanced systems the database will be in a hierarchical format and may include a number of other features such as texture, priority, shading, etc. [C31]

Database Management. The process by which the real time system in the image generator can bring new portions of the database from the system disk as the eyepoint moves around the gaming area. The new data is taken from the available database into the active database. [C31]

Data Certification. The determination that data have been verified and validated. [C31]

Data Logger. A device that accepts Protocol Data Units (PDUs) from the network and stores them for later replay in the same time sequence as the PDUs were originally received.

Data Validation. The documented assessment of data by subject area experts, and its comparison to known or best estimate values. [C31]

Data Verification. The use of techniques and procedures to ensure that data meet constraints defined by data standards and business rules derived from process and data modelling, and that data are transformed and formatted properly. [C31]

Data Verification, Validation, and Certification. The process of verifying the internal consistency and correctness of data, validating that it represents real world entities appropriate for its intended purpose or an expected range of purposes, and certifying it as having a specified level of quality or as being appropriate for a specified use, type of use, or range of uses. [C31]

Dead Reckoning. The process of extrapolating emulation 'entity' position/orientation based on the last known position/orientation, velocity, and (sometimes) higher-order derivatives of position versus time and/or other vehicle dynamic characteristics. [C31]

Defense Communication Agency (DCA). The US Government agency responsible for installation of the Defense Data Network. [C6]

Defense Mapping Agency (DMA). A US Government agency which has responsibility for all DoD mapping related activities. In particular, the DMA produces Digital Radar Land Mass Data, Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD). [C31]

Defense Modeling and Simulation Office (DMSO). The US DOD agency responsible for outlining policy and strategic direction for modeling and simulation within the US military. [C32]

Defence Simulation Internet. DMSO sponsored terrestrial pipeline (wide band packet switching) for the distribution of simulations, designed to be the test bed for defence simulation networking. [C2]

Distributed Computing Environment (DCE). A set of technologies selected by the Open Software Foundation (OSF) to support distributed computing. It defines operating system elements, Application Programming Interfaces (APIs), and tools that support distributed client/server computing and access to distributed data. [C6]

DIS Network Manager. A specified agency with the responsibility of managing the physical network which connects to the Distributed Interactive Simulation (DIS) network. Responsibilities includes approving/accepting DIS participants, scheduling of DIS utilisation, establishing network priorities for DIS applications, monitoring execution of scheduled usage, and co-ordinating functional, technical, and user communities' network requirements. [C31]

Disaggregate. An activity which decomposes an aggregate entity into multiple entities. [C31]

Distributed Interactive Simulation. (1) Any combination of virtual, constructive, and live simulations that are distributed over a network and interact through standardised protocols. (2) IEEE Standard 1278 protocols. [C2] The term "DIS" is often used in the broader context of the definition of Advanced Distributed Simulation. More specifically, DIS may be specified as exact protocols such as DIS 2.0.4 (which are an IEEE Standard). [C29]

E-mail Electronic Mail. A message-passing application that runs on LANs and WANs. E-mail enables users on the network to communicate with each other. [C6]

Emulation. A simulation methodology in which all three elements are replicated using software. [C28]

Entity. An identifiable individual component within a simulation. An entity might be a platform (ship, submarine, aircraft), a munition (missile, torpedo), a human being, or any other component that interacts with the simulation. [C29]

Environment. The physical surroundings such as land, sea, air, space and associated space-time region which characterises the channel or conduit for real interaction between resources. [C1]

Ethernet. A networking architecture for LANs. It uses a bus topology and was originally designed by Xerox Corp. [C6]

Exercise Database. A Distributed Interactive Simulation (DIS) database which includes initialisation data, network, simulation entity, environment and control data. [C31]

Eyepoint. The point in space from which the image calculates its image(s). The design eyepoint is the physical point where the viewer's head is expected to be. [C31]

Federation. In an environment consisting of a collection of data/knowledge bases and their supporting systems, and in which it is desired to accommodate the controlled sharing and exchange of information among the collection, the individual (autonomous, heterogeneous) data/knowledge base systems are termed components, and the collection of components, a federation.

Fidelity. The degree to which aspects of the real world are presented in models and simulators. [C2]

Field Of View (FOV). The area of the image produced by the visual system, normally expressed as a horizontal and vertical angle. [C31]

File Transfer Protocol (FTP). The Internet standard for transferring files from one computing device to another. FTP uses the TELNET and TCP protocols. [C6]

Filtering. Accepting or rejecting Protocol Data Units (PDUs) received on the network based upon specified criteria, which may be dynamically varied. Examples include geographical filtering and entity type filtering. [C31]

Gateway. A networked processor that routes packets of data between two or more networks. Sometimes referred to in the context of internet. [C6]

Government Network Management Profile (GNMP). Specifies the syntax and semantics of the management information needed to support the control monitoring of networks. GNMP-compliant products can be separate from GOSIP-compliant products. [C6]

Government OSI Profile (GOSIP). A set of specifications defining OSI-compliance required by government agencies purchasing networking equipment. [C6]

Graphical User Interface (GUI). A graphics-based user interface that incorporates icons, pull-down menus, and a mouse. GUIs are found in Macintosh, Windows, and OS/2 operating systems. [C6]

Hardware. A non-reprogrammable technology. [C1]

Hardware-in-the-Loop domain. Simulations that involve actual hardware components of military systems (e.g., a missile seeker head) integrated with simulations of the other components of the overall system. [C35]

Higher Level Architecture (HLA). An object oriented approach towards simulator and simulation interoperability. Currently a draft IEEE set of standards, HLA may provide greater interoperability between certain networked simulations, and increased interoperability among virtual, live, and constructive simulations. [C39]

Host Computer. A computer that supports one or more simulation applications. All host computers participating in a simulation exercise are connected by a common network. [C31]

Human interactive domain. Includes the sub-categories of Live, Virtual and Constructive simulation. [C35]

Hybrid systems. Systems which use emulated control logic and real hardware for the interface. [C28]

Image Generator (IG). The generic term which refers to the collection of hardware used for creating computer generated imagery. The term normally implies a significant amount of special purpose hardware and real time operation. [C31]

Institute of Electrical and Electronics Engineers (IEEE). A US based organisation that provides the accreditation and certification of various standards. The latest working version of DIS, DIS 2.1.4, is enunciated within the IEEE standard 1278.1a. [C6]

Information. A set of conclusions which may include measures of uncertainty. [C1]

Information base. An implementation where information is represented and stored. [C1]

Inheritance. (In Object Oriented Programming (OOP)). The features of a child object which may be attributed to a parent object.[C1]

Integrated Services Digital Network (ISDN). A type of wide-area communication service provided by long-distance and regional telecommunications service providers. [C6]

Interface. An entity of a composite object which is directly responsible for its observed attributes and behaviour. [C1]

International Standards Organisation (ISO). A worldwide organisation that develops standards in all product areas. ISO is responsible for defining the standard for the OSI Reference Model. [C6]

International Simulation Advisory Group (ISAG). International interest and reference group concerning modelling and simulation. One goal is to provide a co-ordination focus for major international interests in M&S standars carried out by SISO. Website: www.isag.cx. [C38]

INTERNET. A worldwide network based on the TCP/IP protocol suite and originally funded by DARPA. [C6]

Interoperability. The ability of simulations to provide services to and accept services from other simulations and to use the services so exchanged to enable them to operate effectively together. Two or more simulations/simulators are DIS interoperable for a given exercise if they are DIS compliant, DIS compatible, and their performance characteristics support a fair fight to the fidelity required for the exercise. [C29]

IOTTF. Integrated Operations Team Training Facility. Acronym is shown in figure 3 in Defence Simulation Master Plan, and denotes the combined DDG/FFG ship operations room simulator at HMAS Watson. [C33]

Joint. For the purpose of this publication, "joint" refers to those modelling and simulation items and activities that share participation or support of more than one Service. [C2]

Latency. The portion of overall transport delay (time) which is in excess of delays in the actual vehicle being simulated. [C31]

Local Area Network (LAN). A network designed to connect computers and peripherals over relatively short distances. Such a data network provides a high data rate interconnection between network nodes in close physical proximity. LANs are defined by the IEEE 802.X series of standards. [C2]

Live Simulation. A representation of military operations using military personnel and equipment which simulate experiences achieved during actual operational conditions. Live simulation participants perceive the environment via actual sensors or directly

with their own eyes. [C2] N.B. The authors consider that live simulation is a subset of training. Not all training is simulation.

Measure of Effectiveness (MOE). An inherent capability parameter which can only be measured in the course of accomplishing a mission. [C1]

Measure of Performance (MOP). An inherent capability parameter which may be measured independently of the mission. It is a measure of how the system/individual performs its functions in a given environment (eg, probability of detection, reaction time, number of targets nominated). [C1]

Mission Rehearsal. Practicing planned tasks and functions critical to mission success using a true-to-life, interactive representation of the predicted operating environment. [C2]

Model. A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process. [C2]

Modelling and Simulation (M&S). The use of models, including emulators, prototypes, simulations, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modelling" and "simulation" are often used interchangeably. [C35]

Module. A generic name for a physically or functionally aggregated set of activities, processes, services, layers or resources or some combination thereof. [C1]

Multicast. A transmission mode in which a single message is sent to multiple network destinations, i.e. one-to-many. [C31]

Network Filter. A system of network addresses to selectively accept or reject Protocol Data Units received from the network. [C31]

Node. A general term denoting either a switching element in a network or a host computer attached to a network. [C31]

OPC. Offshore Patrol Combatant. Acronym is shown in figure 3 in Defence Simulation Master Plan, and denotes the possible inclusion of a future OPC ship operations room simulator which might be included in the Maritime Warfare Training Centre Node at HMAS Watson. [C33]

Open System Environment. The fielding of hardware and software products that are interoperable and portable. The objective is to promote competition by allowing systems developed by multiple vendors and nations to interoperate through a common set of computer and communication protocols. [C2]

Paradigm. A conceptual model, a metaphor.[C1]

Platform. A generic term used to describe a level of representation equating to vehicles, aircraft, missiles, ships, fixed sites, etc. in the hierarchy of representation possibilities. Other representation levels include Units (made up of Platforms) and components or modules (which make up Platforms). [C31]

Process. A set of interdependent activities. [C1]

Program. An executable body of (computer) code. [C1]

Programmable. Capable of being encoded to execute more than one program. [C1]

Proponent. The agency or organisation that has primary responsibility for the life cycle of an assigned model or simulation. [C2]

Protocol. A set of rules governing a data communications procedure that must be followed to enable two or more computing devices to exchange and read instructions and messages. [C6]

Protocol Data Unit (PDU). A structured message which transfers essential data of a specific type from one Distributed Interactive Simulation (DIS) entity to another and allows them to participate in a common exercise. [C2]

Prototype. A preliminary type, form, or instance of a system that serves as a Model for later stages or for the final, complete version of the system. [C31]

Real World. The set of real or hypothetical causes and effects that simulation technology attempts to replicate. When used in a military context, the term is synonymous with Real Battlefield to include air, land, and sea combat. [C31]

Real Time. Simulated time with the property that a given period of actual time represents the same period of time in the system being modelled. [C31]

Refresh Rate. The rate at which the image is redrawn on the display device. [C31]

Resolution. The degree of detail and precision used in the representation of real world aspects in a model or simulation. More specifically, resolution is used as a measure of the ability to delineate picture detail. [C2]

Router. A device or system used to connect separate LANs and WANs into an internetwork. It also routes data traffic between the networks after selecting the transmission path or paths. Routers were called gateways during the early years of Internet development. [C6]

Server. A process (also the computing device enabling the process) in a distributed computing system that provides a service in response to requests from client computing devices. [C6]

Simple Mail Transfer Protocol (SMTP). A protocol within the TCP/IP protocol suite used to transfer mail across an internet. [C6]

Simple Network Management Protocol (SNMP). Part of the TCP/IP protocol suite. It enables a management station to configure, monitor, and receive alarm messages from network devices. [C6]

Simulation. A method for implementing a model over time and a technique for testing, analysing, or training in which real-world systems used, or real-world and conceptual systems are reproduced by a model. Most combat simulations are implemented as computer programs. [C2], adapted from [C6]

Simulation Based Acquisition. A process involving an integrated application of M&S that supports military systems from initial concept development through the acquisition phase to in-service support. [C35]

Simulation Interoperability Standards Organisation (SISO). An organisation dedicated to the promotion of modelling and simulation interoperability and re-use for the benefit of diverse M&S communities, including developers, procurers, and users, world-wide. SISO provides an open forum that promotes the interoperability and re-use of models and simulations through the exchange of ideas, the examination of technologies, and the development of standards. Website: www.sisostds.org. [C38]

Simulator. A device which employs simulation to replace a real world system or apparatus, eg for training purposes. A simulator generally has three elements - a modelled process which represents the real world system, a control system, and a man-machine interface. [C28]

Software. A body of code intended for programmable hardware. [C1]

State. A set of variables which characterise object entities and span all possible perspectives. [C1]

Stimulation. A simulation methodology which has a synthetic environment generating signals which are input to the real control system and which uses the real hardware interface. [C28]

Stochastic. Pertaining to a process, model, or variable whose outcome, result, or value depends on chance.

Synthetic Environment. Computer generated representation of the real world. [C2]. Most often used to recreate a virtual battlefield in which simulations linked via networks can conduct and fight a highly realistic battle. [C29]

Synthetic Theatre of War (STOW). A US DoD technology demonstration for DIS within an operational exercise. STOW was proposed by the US Defence Advanced Research Projects Agency (DARPA) to provide a joint virtual theatre of war for up to 50 000 entities by 1997. It was planned to demonstrate the cost-effectiveness of using DIS for joint warfare training, planning, mission rehearsal, and to support acquisition and analysis programs. At the completion of the project, whilst successful, less than 10,000 entities were included. [C29]

TELNET. The TCP/IP protocol that enables a terminal attached to one host to establish remote terminal connection service. It is the application that allows the user to connect to another computer, log in, and start a remote terminal session. [C6]

Transmission Control Protocol (TCP). The TCP/IP protocol that provides reliable, connection-oriented data transmission between a pair of applications. [C6]

Transmission Control Protocol/Internet Protocol (TCP/IP). The only major nonproprietary protocol suite with a large installed base world-wide. It was developed under the guidance of the US Department of Defense and is the backbone protocol for the Internet. [C6]

Unix. An operating system developed at AT&T Bell Laboratories based on the principles of open systems. It runs on a wide variety of computers, and has been widely acknowledged as the optimal operating system in a distributed computing environment. [C6]

Validation. The process of determining the extent to which a model or simulation is an accurate representation of the real world from the perspective of the intended uses of the model or simulation. [C2]

Verification. The process of determining that model or simulation implementation accurately represents the developer's conceptual description and specifications. Verification establishes the extent to which the model or simulation has been developed using sound and established software engineering techniques. [C2]

Virtual Modelling and Simulation. A simulation involving real people operating simulated systems. The human-in-the-loop in virtual simulations has a central role through the exercise of motor control skills (e.g., flying an aircraft), decision skills (e.g., committing fire control resources to action), or communication skills (e.g., as members of a C4I team). [C35]

Virtual Reality. A group of technologies which provide a human user with experience of artificial worlds through the senses of vision, sound, touch and feel. The technologies consist of a data base processed by a computer with sophisticated graphics, with interaction provided by a head-set or helmet-mounted display, a data glove, and a head-tracking position sensor. 3D audio can be added, and a number of tactile and force feedback devices are under development. [C34]

War Games. Manual or computer simulations with human players making some or all of the key decisions. War games are themselves models in that they attempt to represent a system (e.g. the nations participating in war). However, they also require the use of specialised sub-models; modern war games typically employ interruptable or highly interactive simulations, with the opposed players making periodic decisions about how to deploy and employ forces. These decisions are entered into the computer and the simulation is resumed. A few war gaming models can be used interactively in games and can also be used without user intervention, as closed simulations, by substituting decision models.

Wide Area Network (WAN). A network connecting computing devices and peripherals over long distances. The transmission medium is usually a long-distance carrier but can also be a private dedicated network. [C6]

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19. ABSTRACT

To address long standing problems with modelling and simulation, the US Department of Defence through the Defense Modeling and Simulation Office (DMSO) has initiated a comprehensive series of programs. These programs aim to promote interoperability, code and model reuse, data standardisation, common conceptual models of military operations, and Validation, Verification & Accreditation (VV&A), among other important issues, through a Common Technical Framework. A key issue for Australia is the means of networking simulators together. The US DoD has mandated the High Level Architecture (HLA) which has technical advantages over the previous standard, Distributed Interactive Simulation (DIS). The advantages and disadvantages of each approach are discussed in the Australian context. Other related programs such as the Synthetic Environment Data Representation and Interchange Specification (SEDRIS), Conceptual Models of Mission Space, Master Environment Library, Data Engineering, and VV&A programs are discussed in the Australian context. The authors recommend a cautious approach to the introduction of HLA into the ADO following the US experience. Through appropriate Defence Exchange Agreements the ADO can work with the US and our other allies (particularly the UK) to ensure that ADF in-service training systems will migrate to HLA while retaining interoperability.

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